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How do weeds affect us all?

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Editor's note: Below is the full text of a later paper on the same topic presented by Beck at the Grazing Lands Forum VIII, "An Explosion in Slow Motion: Noxious Weeds and Invasive Alien Plants on Grazing Lands."

What is a weed?

Many definitions of weeds have been created and historically, all definitions are centered around human activities. For example, the Weed Science Society of America defines a weed as 'a plant out of place'; Emerson thought a weed was 'a plant whose virtues have yet to be discovered'; and Toffell defined a weed as 'a plant that interferes with the management objectives of a given area of land at a given point in time'. Anthropomorphic definitions of weeds are not inherently bad as humans evolved on earth and we use our natural resources and weeds are plants that inhibit our efficient use of natural resources. However, there are physiological and biological characteristics of the group of plants that we call weeds and careful examination of these factors will help one to better understand why weeds are problematic.

Grime (1979) indicated that two basic external factors limit the amount of plant material found in any given environment; i.e., stress and disturbance. Stress includes environmental phenomena that reduce production such as limiting light intensity, water availability, nutrients, or optimal temperatures for growth. Disturbance is the partial to total disruption of plant biomass typically caused by fire, flooding, mowing, tillage, grazing, etc. If one considers the four extremes of stress and disturbance (e.g. high and low stress v. high and low disturbance) four outcomes for plant production ensue. Plant death occurs under high stress and high disturbance; the development of a population of stress tolerators occurs under high stress and low disturbance; a population of ruderal plants establishes under low stress and high disturbance; and competitor species dominate under low stress and low disturbance.

Thus, in an environment limited by abiotic (physical factors such as climate, fire, flooding, etc.) and biotic (insect predators, plant pathogens, plant competition, etc.) factors, three evolutionary strategies for plants occur. Stress tolerators are those plants that reduce allocations to vegetative growth and reproduction to ensure a population of relatively mature individuals in a limiting environment; competitors maximize resource capture in productive but relatively undisturbed environments; and ruderals are plants with short life cycles and high seed output that are found in highly disturbed environments and occupy the early stages of secondary succession. Few plants fall into these extreme categories and most are combinations of the three evolutionary strategies. Many herbaceous annual, biennial, and perennial weeds can be characterized as competitive ruderals. These plants occupy sites where dominance by true competitors does not occur because of disturbance; occasional disturbance is expected but frequent or severe disturbance would favor ruderal plants.

Environments favoring competitive ruderals would include meadows, seasonal grasslands, rangeland subject to seasonal disturbance (e.g. grazing), floodplains, eroded areas, lake and ditch margins, and arable lands. Thus, most weedy species occupy land in early to intermediate stages of secondary succession.

Weed impacts; So what's the big deal?

Noxious weeds are typically plants of foreign origin and, thus, did not evolve in North America. When these plants were inadvertently or otherwise imported into the United States, biotic factors, such as insect predators and plant pathogens, that evolved with the weed at its points of origin were not imported. Thus, in their 'new home', alien plant populations are regulated only by abiotic factors and this is not enough to keep their populations from increasing exponentially. For example, leafy spurge (*Euphorbia esula*) was introduced into the Red River Valley of North Dakota and Minnesota in the 1880's and this plant infests over 1 million acres in North Dakota alone today (Lacey *et al.*, 1985). Spotted knapweed (*Centaurea maculosa*) was introduced into Gallatin County, Montana, in the 1920's; by 1984 it had spread to all 56 Montana counties occupying over 2 million acres and today, over 4.7 million Montana acres are infested with this weed (Lacey *et al.*, 1986). Yellow Starthistle (*Centaurea solstitialis*) was introduced into California in 1869 near Oakland; by 1965 over 1.9 million acres were infested with yellow starthistle and by 1985, infestations increased to 7.9 million acres (Thomsen *et al.*, 1989). Purple loosestrife (*Lythrum salicaria*) infestations were studied from 1965 through 1978 at the Montezuma National Wildlife refuge in New York and biomass yield of purple loosestrife increased over this time from 0 percent of that harvested in 1965 to 90 percent in 1978 (Thompson *et al.*, 1987). A recent study in Colorado assessing the encroachment of Dalmatian toadflax (*Linaria genistifolia spp.* dalmatica) on rangeland showed over 4 years that this weed increased 322 percent in cover, 1250 percent in shoot density per acre, while crested wheatgrass cover decreased 172 percent (K.G. Beck unpublished data, Colorado State University, Ft. Collins).

We have significant alien plant infestations occupying rangeland and other natural resource areas in the United States and Canada today. Spotted knapweed occupies over 7.2 million acres in nine states and 2 Canadian provinces (Lacey, 1989). Diffuse knapweed (*Centaurea diffusa*) occupies over 3.2 million acres in 10 states and 2 Canadian provinces (Lacey, 1989). Russian knapweed (Acroptilon repens) occupies over 1.4 million acres in 9 states and 2 Canadian provinces (Lacey, 1989). Yellow starthistle occupies over 9.4 million acres in 10 states and 2 Canadian provinces (Lacey, 1989; Maddox and Mayfield, 1985). Leafy spurge infested over 2.5 million acres in 30 states in 479 U.S. counties as of 1979 (Lacey et al., 1985). Downy brome or cheatgrass (*Bromus tectorum*) infests over 101 million western U.S. acres and is listed as the dominant plant in the Intermountain West (Mack, 1981). A recent article in the Atlantic (Devine, 1993) laments the displacement of native bunchgrasses from downy brome encroachment in the west.

Cropland and forage production impacts:

In 1984, the average annual yield loss in 64 U.S. and 36 Canadian crops caused by weeds was $7.4 billion and $909 million, respectively (WSSA, 1984). Leafy spurge reduces the cattle carrying capacity of rangeland in North Dakota and Montana by 75 (Thompson *et al.*, 1990) and 63 percent (Bucher, 1984), respectively. Forage losses in Montana from spotted knapweed infestations were valued at $4.5 million in 1984 and if spotted knapweed continues to spread in Montana at its current rate, at least 33 million acres will be infested by 2009 causing $155 million in annual forage losses (Bucher, 1984).

Soil stability and water quality impacts:

Soil and water losses have occurred and continue to occur on millions of acres where grass communities have been replaced by tap-rooted plants. Lacey *et al.* (1989) measured surface water runoff and sediment yield (soil erosion) during a 30 minute simulated rainfall event on spotted knapweed dominated rangeland compared to native bunchgrass dominated sites. They found surface water runoff and soil erosion were 56 and 192 percent higher, respectively, on spotted knapweed dominated sites. This indicates that the presence of spotted knapweed on Montana rangeland is detrimental to soil and water resources. Soil on spotted knapweed dominated sites is eroded to a much higher degree compared to bunchgrass communities and water infiltration into the soil profile is less. This could and most likely has contributed to the displacement of native grasses because soil-water relationships have been altered due to the presence of spotted knapweed. This equates to greater sedimentation of streams, rivers, and lakes and will negatively impact fisheries.

Wildlife forage and habitat impacts:

The influence of noxious weeds on wildlife is not well understood or documented, but a few facts exist and the impact appears mostly to be detrimental. In western Montana, elk (Cervus canadensis) use of rangeland was estimated by counting pellet groups and there were 1575 pellet groups per acre in bunchgrass sites compared to 35 pellet groups per acre in spotted knapweed dominated sites (Hakim, 1975). Several studies indicated that spotted knapweed was not found in elk diets (Kufield, 1973; Lovaas, 1958; Mackie, 1970; Morris and Schwartz, 1957; Stevens, 1966). However, a recent study by the University of Montana indicates that elk grazed spotted knapweed in early winter, but in late winter, their diets were primarily grasses (Bedunah and Carpenter, 1990). Little to no spotted knapweed was found in their diets during February, March, or April even though the study area was dominated by spotted knapweed. Elk and deer eat spotted knapweed seedheads in winter and rosettes leaves in spring in the Bitteroot Valley of Montana; however, they may do so because of availability and not because of preference. In another study, spotted knapweed was common on mule deer (Odocoileus hemionus) range in Montana although the plant was not detected in their diets (Guenther, 1989). A game damage survey to alfalfa was conducted in 1986 in northeastern Wyoming, an area badly infested with leafy spurge; feces were examined histologically to determine which plant species were being consumed and they found no leafy spurge in deer diets. In North America, purple loosestrife encroaches upon and displaces desirable food plants and waterfowl nesting sites (Thompson, 1987). Cattails (*Typha latifolia*) were displaced by purple loosestrife competition, exacerbated by the selection pressure placed on cattails by muskrat feeding; and when these sites are dominated by purple loosestrife, muskrats move out. Purple loosestrife infestations make waterfowl broods more susceptible to predation because of the increased cover provided by tall purple loosestrife and the lack of a direct route from water to nesting sites. Certain waterfowl species, e.g. canvasback (Aythya valiisineria) and black tern (Chlidonia niger) prefer to nest on relatively open sites such as abandoned muskrat nests built from cattails. With purple loosestrife encroachment and displacement of cattails and other riparian plants that provide these sites, suitable nesting sites are decreased.

Noxious weeds are not entirely harmful to wildlife. A Montana Outdoors article indicates that weeds provide cover, habitat diversity, and a source of feed for many game and non-game birds (Wiegand, 1977). It is worth noting, however, that the tendency of noxious weeds to form monocultures would decrease habitat biodiversity once this occurred. In British Columbia, knapweed rosettes were found to be important components in the diets of deer and elk in early spring (Miller, 1990). A recent study in Colorado and Wyoming indicates that three times as many small mammals frequented Russian knapweed infested rangeland compared to adjacent noninfested sites (R. Olson, University of Wyoming, personal communication). Adaptation occurs as evidenced by one small mammal, a harvester mouse, using the Russian knapweed infested sites and this mamumal may serve to spread the weed as they cache seeds.

Species diversity and impact on native plant habitat:

Many noxious weeds dominate plant communities and tend to form monocultures and this obviously negatively impacts native biological diversity in the United States. Downy brome communities in the Intermountain West are poor in species composition compared to steady state (climax) sagebrush/bluebunch wheatgrass (*Artemisia tridentata/Agropyron spicatum*) communities (Rickard and Cline, 1980). Displacement of native plants by spotted knapweed was assessed in Glacier National Park in Montana from 1984 through 1987 (Tyser and Key, 1988). These sites were originally classified as Idaho fescue (*Festuca idahoensis*) and rough fescue (*Festuca scrabella*) dominated plant communities. Spotted knapweed impacts to native plant communities were assessed on perimeter, fringe, and core weed infestations. These researchers found the species richness gradient to be inversely proportional to spotted knapweed stem density; i.e., the more spotted knapweed stems per unit area, the fewer number of plant species present. Species richness declined as one moved along the transects from the perimeter to the core infestations (species richness ranked perimeter> fringe> core). Spotted knapweed stem density was the only variable associated with the species richness effect. These researchers further classified plants in the fringe infestations as common, uncommon, or rare. Of the 38 species evaluated in 1984, 31 were reclassified at the same frequency in 1987. However, seven of the original species were reclassified into lower frequency categories in 1987 (*Galium boreale*, *Hieracium umbellatum*, *Potentilla arguta*, *Potentilla gracilis*, *Silene parryi*, *Stipa occidentalis*, and *Tragopogon dubuis* - note the last species was an uncommon, weedy, alien). Six species were classified as common in 1984 and five of these remained in this category in 1987. Of the 21 uncommon species in 1984, only 16 remained as such in 1987 with six being reclassified as rare in 1987. Additionally, five rare and two uncommon species found in 1984 were not present in 1987 (*Agropyron spciatum*, rare; *Castilleja cusickii*, rare; *Collomia linearis*, rare; *Heuchera cylindrica*, rare; *Lithospermum ruderale*, rare; *Stipa occidentialis*, uncommon; and *Tragopogon dubius*, uncommon and alien). Additionally, native plants are being displaced in Utah by dyer's woad (*Isatis tinctoria*) (West and Farah, 1989) and in California by yellow starthistle (Maddox and Mayfield, 1985).

The impact of noxious, alien weeds on rangelands and other natural resource areas are not well understood nor documented. The weed science community has spent a lot of time leaming how to control weeds v. understanding their biology, ecology, and impacts. This trend is changing and with increased opportunities for grant supported research in these areas, a greater understanding will occur. Nonetheless, aggressive, alien plants will continue to displace native plants in their habitats primarily due to a lack of biotic pressure placed on alien plant populations (no biological control - in the absence of other control measures). This is further exacerbated by the rapid rate of spread by alien weedy species and the difficulty associated with effectively managing all infestations in any given year because infestations are very large and scattered across landscapes.

Open space and wilderness area impacts:

Open spaces are prime areas for alien plant invasion. Open spaces associated with cities and counties typically are former grazingland or abandoned farmland. Thus, open spaces have been disturbed to one degree or another and subject to secondary succession - weed invasion. Open space infestations serve as sources for new infestations on adjacent land and land farther away. For example, open spaces along Colorado's Front Range communities are dominated by alien plants. Boulder City and County Open Space ground is infested with diffuse knapweed, spotted knapweed, Russian knapweed, Canada thistle, field bindweed (*Convolvulus arvensis*), Dalmatian toadflax, downy brome, and musk thistle; Cherry Creek State Park in the greater Denver Metropolitan area is badly infested with diffuse knapweed, leafy spurge, musk thistle, Canada thistle, and field bindweed and these infestations are spreading along Cherry Creek into the South Platte River which flows into Nebraska; Fort Collins open space areas are infested with leafy spurge, Canada thistle, musk thistle, diffuse knapweed, field bindweed, downy brome, puncturevine

(Tribulus terrestris), and these plants are particularly troublesome along the Poudre River corridor which flows into the South Platte, thus, these infestations are spreading into Weld, Morgan, Logan, and Sedgwick Counties in Colorado and into Nebraska.

Backpackers and horsepackers inadvertently spread alien plants into wilderness areas. Seeds on clothing, packs, animals, or in contaminated hay brought into wilderness, or excreted in feces by domestic animals, are sources for new infestations. For example, the Rawah Wilderness in Colorado is infested with musk thistle and it is spreading rapidly because of the plant's biology and lack of weed management input. Canada thistle infestations in Rocky Mountain National Park have been the object of interest for the past 3 years. Infestations started along horse and foot trails and have spread from there into native plant communities (T. Mclendon, Colorado State University, personal comununication). Dry, upslope conditions, thick canopies from woody species, and well-established grass meadows (especially wet meadows) inhibited Canada thistle invasions. Canada thistle populations appear to thin with time and become part of the plant community in many instances, in the absence of further disturbance. However, even minor disturbance from elk grazing promoted Canada thistle invasion and establishment into grasslands.

Plant succession dynamics impacts:

Weeds (alien or native) would be classified under 'natural systems' as pioneers, invaders, or increasers. Disturbance creates an opportunity for secondary succession to occur and weeds will occupy the site initially. Depending upon the degree of disturbance, annual weeds will occupy the site first and be replaced with time by herbaceous perennial weeds. In abandoned farmland, the systematic replacement of early and intermediate plant seral stages occurs over time until a steady state community develops - not necessarily identical to the pristine community before fanning was practiced; this is termed old field succession. The time associated with these changes varies with climate, soil nutrient status, weed species present, availability of native plant propagules and species composition thereof.

The impact of noxious weeds on plant succession dynamics of grazinglands is not well understood. Patches of noxious weeds, such as leafy spurge or Russian knapweed, survive for extended periods. For example, a Russian knapweed stand in Saskatchewan has survived over 75 years (Watson, 1980). Presumably because these plants are competitive ruderals, they should be replaced over time by those plants that occupy later stages of succession. However, the time frame is unknown and apparently may be long relative to a human perspective. Alien plant persistence is further exacerbated by the lack of biotic pressure on these plant communities in North America. Furthermore, if alien plant species eventually yield to later successional species (presumably desirable native species), the time that they occupy an area may render that area less useful to useless for productive purposes (e.g., interfere with any agricultural operation, forestry, wildlife foraging, or recreational use).

Human health hazard impacts:

Virtually any pollen producing plant has the potential of affecting hay fever sufferers. In Colorado for example, ragweed (*Ambrosia spp.*) - native plants - cause significant problems for those with respiratory allergies. However, kochia (*Kochia scoparia*) and Russian thistle (*Salsola iberica* and *S. collina*) cause equivalent problems for those with hay fever. Latex in leafy spurge can cause irritation to broken skin, eyes, or simply may cause a dermal rash. Several volunteers in Boulder County, Colorado that hand-pulled diffuse and spotted knapweeds contracted a dermal rash from these weeds. This is another area where weed impacts are not well understood or documented.

Economic impacts:

The common denominator for human endeavors is our means of barter - i.e., money. Economic impacts caused by alien weeds on grazinglands has not been thoroughly documented but some information is available. Scotch thistle (*Onopordum acanthium*) infestations in northern California cause annual losses to ranchers equating to $60.50/acre on wet meadows, $39.50/A on wheatgrass stands, and $20.16/A on cheatgrass rangelands (Hooper *et al.*, 1970).

The most thorough study on weed impacts on grazinglands was conducted by the Agricultural Economists at North Dakota State University. They determined the direct impacts caused by leafy spurge on North Dakota grazinglands and wildlands then used an input-output model to determine secondary effects (Leistritz *et al.*, 1993). Direct annual losses from leafy spurge included $8.7 million in reduced personal incomes for North Dakota cattle producers and an additional $14.4 million reduction in rancher spending (i.e. lost cash outlays) due to reduced livestock production. In 1990, leafy spurge infestations reduced cattle carrying capacity by approximately 580,000 animal unit months (AUMs) or enough to support 63,100 cows for 7.5 months. Total annual direct grazingland losses were valued at $23.1 million. Indirect grazingland losses caused by leafy spurge infestations totalled $53.2 million and these losses were incurred by businesses outside of livestock production but caused by reduced income and expenditures from the cattle industry. Annual direct losses due to leafy spurge on North Dakota wildland totalled $2.9 million because of reduced wildlife associated recreation. An additional $0.7 million direct wildland loss was estimated in reduced soil and water conservation caused by leafy spurge infestations. Indirect annual losses to North Dakota wildland from leafy spurge were caused by reduced expenditures within their economy from direct losses and totalled $7.4 million. Therefore, total direct and indirect annual losses to North Dakota grazingland and wildland caused by leafy spurge were valued at $87.3 million! The majority of indirect losses in grazingland and wildland was in the household sector and totalled $28.7 million annually and equated to approximately $26.00/A infested with leafy spurge. Additionally, current infestations cause a reduction in over 1,000 jobs per year in North Dakota.

Summary and recommendations

The negative impacts caused by noxious weeds are very real and clear where recognized. Unknown impacts exist and must be determined so we can better decide where to focus our attention. Grazingland, wildland, farmland, native habitat, open spaces, and urban landscapes all are negatively impacted by the presence of alien plant species. The domino effect from the economic impacts caused by the presence of alien plant species indicates that our daily lives indeed are negatively impacted by this 'mundane' group of plants.

We can choose to act and invoke integrated weed management strategies to reduce infestations and their impacts. Or, we can choose not to act and allow alien plants to continue to displace desirable plants thus, destroying the native biological diversity of our country and the value of our grazinglands and wildlands and further negatively impact our nation's economy. It seems very unnecessary and illogical for this latter scenario to occur!

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