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Yellow Starthistle

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Yellow Starthistle

Biology and Management in Pasture and Rangeland

L.W. Lass, J. P. McCaffrey, D.C. Thill, and R.H. Callihan

Introduction

Yellow starthistle (*Centaurea solstitialis* L.), an introduced Eurasian weed, presently infests nearly four million acres in the Western States. This species has been declared noxious under authority of weed laws in several western states. This means that landowners are required to prevent the weed from growing on their land, unless specifically exempted. Since yellow starthistle infests such a large geographic area, it is likely that the weed is here to stay, but with proper management practices it need not dominate the landscape.

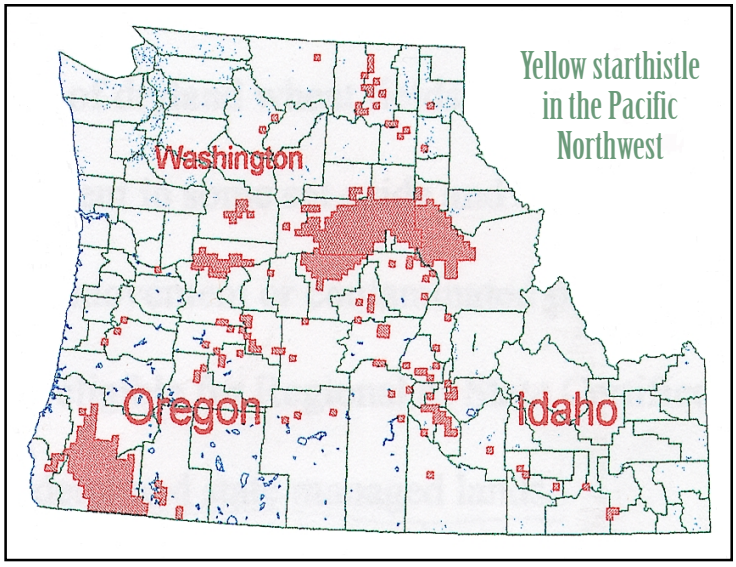
Where is it a problem?

The most intensive yellow starthistle infestations occur on arid to semiarid non-cultivated land where it reduces desirable plant biodiversity and provides major seed sources for spread to other ground. By far the most serious yellow starthistle invasion has occurred on marginal rangeland and non-crop land, but cultivated lands including dryland grain, set-aside, Conservation Reserve Program (CRP), grass and legume seed crops, and irrigated pastures also are susceptible to invasion by yellow starthistle. It infests urban areas, roadsides, and many types of non-arable land. The largest infestations in Idaho are in Clearwater, Idaho, Latah, Lewis and Nez Perce counties (Fig. 1). It has begun invading southern Idaho at numerous, but scattered locations. It is widespread in California, has been spreading rapidly in eastern Washington and Oregon, is established in Utah, and has recently been found in Montana. Infestations found in Arizona, New Mexico, and Nevada have been recently established primarily by transporting seed on construction equipment.

Impact on Agriculture

Yellow starthistle causes serious economic loss. In rangeland, yellow starthistle is very competitive, forming dense stands that drastically reduce and frequently eliminate forage production when compared to perennial grasslands. Where the previous vegetation has been annual grasses such as downy brome, medusahead rye, or annual fescue, yellow starthistle stand densities commonly exceed 500 plants per square yard, and the vegetation is more than 90 percent yellow starthistle.

Cattle will graze yellow starthistle in early spring if preferred species are scarce. Yellow starthistle does not provide maintenance nutrition requirements for most animals, so cattle subsisting on it usually will lose weight or weight gain will be limited. As yellow starthistle plants mature, they become unpalatable and livestock avoid the sharp, spiny plants.



Yellow starthistle occasionally infests the edges of dryland wheat fields where it reduces the yield and hampers harvesting. It has become prominent in some set-aside and CRP land and has appeared in new forage plantings as a result of seed movement or contaminated planting stock. Hay fields contaminated with yellow starthistle are not eligible for Regional or State Certified Hay Programs. Uncertified hay cannot be used on federal and state managed lands.

Toxicity

Yellow starthistle poisoning has occurred in horses and some laboratory test animals, but has not been reported in cattle and other classes of livestock. Clinical signs of the poison do not become evident until the horse eats yellow starthistle in amounts nearly equivalent to the animal's body weight. The disease symptoms may not appear until several weeks after the horse has eaten the yellow starthistle. Effects of sub-lethal doses of yellow starthistle may be first noticed as abnormalities in walking or other movement. Early symptoms may resemble Parkinson's disease where muscle movement is jerky and the animal may tremble (see video at http://soils.ag.uidaho.edu/yst/Biology/Toxic/Toxic.htm).

Diagnostic symptoms of yellow starthistle poisoning in horses, often called chewing disease, is the inability to eat or drink. In later stages, the muscles of the lips, face and tongue become stiff and swollen, giving the horse a fixed or frozen expression. As the syndrome continues, the horse's legs become stiff and may tremble. These symptoms result from permanent brain damage caused by grazing on yellow starthistle. Affected horses may never recover, and severely affected animals eventually die of thirst and starvation.

Biological and ecological factors favoring yellow starthistle infestation

Yellow starthistle was introduced into the United States as a result of seeds being brought from central Europe. The initial introduction was probably from contaminated hay and bedding for horses brought to Mexico and California in during the mid-1800's. The reasons for the widespread problem in the northwestern U.S. are a complex set of circumstances: (1) Native perennial bunchgrasses that originally dominated the region were destroyed by overgrazing. (2) Alien annual grasses arrived as seed contaminants, at the time of the original overgrazing. The new invading annual grass seedlings out-competed bunchgrass seedlings, so the rangelands were soon dominated by annual grasses. (3) Deep rooted perennials like St. Johnswort, also called goatweed opportunistically utilized resources available in the annual grass community and dominated the ecosystem until it was controlled by the goatweed biocontrol agent. (4) Yellow starthistle invaded the rangelands following the biological control of St. Johnswort. The removal of the St. Johnswort allowed the annual grasses to rapidly establish preventing the return of the native perennial grass seedlings by competition. Yellow starthistle was able to utilize more resources than the annual grasses and as a result yellow starthistle populations expand rapidly. (5) Yellow starthistle seeds that were brought into the country did not carry the natural enemies that suppress the weed in its native Eurasian habitat, and (6) yellow starthistle seeds remain alive in the soil for up to 10 years, enabling the weed to reappear even when traditional herbicide control methods were pursued.

The combination of these six factors continues to enable yellow starthistle to successfully dominate vegetation in vast areas. Any long-term solution to the yellow starthistle problem must address the basic causes: suppression of the perennial grasses, presence of annual grasses, presence of yellow starthistle, absence of natural enemies, and seed persistence in the soil. Short-term solutions that suppress yellow starthistle do not work. However they may be part of the long-term solution. In general, the habitats must be changed to stabilize the impacted areas.

Rates of spread

University of Idaho's field surveys show that yellow starthistle has been invading Idaho lands at the rate of about 6,000 acres per year since 1981. Growing from about 25 acres in northern Idaho in the early 1950's, the estimated infestation size by 1998 was 600,000 acres. The annual rate of spread in newly invaded areas is several

hundred-fold initially, and steadily reducing as most of the available habitat becomes infested. From 1950 until 1980 the average rate of the increase in northern Idaho was apparently about 30 percent per year. Now that it has invaded most of the land to which it was adapted in northern Idaho, the expansion has slowed to about 3 to 5 percent per year and is filling in gaps between established infestations. Northern Idaho still contains more than 95 percent of the state's yellow starthistle. However, most of Idaho's 20 million acres of rangeland, primarily in southern Idaho, are susceptible to yellow starthistle invasion. If present rates of the invasion continue, most susceptible areas throughout the Northwest are expected to contain yellow starthistle within the next 30 years. Better private and public resource management can slow the rate of the invasion.

Weed Habitat

Nearly all rangeland in the sagebrush-grass and short-grass vegetation zones of the semiarid to subhumid western U.S. is potentially susceptible to yellow starthistle invasion. This includes about 40 percent of Idaho. Yellow starthistle thrives best on warm, deep, well-drained soils receiving 15 to 30 inches of precipitation annually. However, it survives and forms dense infestations dominating other annual plant species in unproductive soils, including shallow, rocky sites with as little as 10 inches of annual precipitation. Key indicator species that characterize sites susceptible to yellow starthistle are downy brome and annual fescues. Where conditions enable these annual grasses to persist, yellow starthistle normally is able to invade.

The adaptability of yellow starthistle to grasslands has enabled it to become solidly established in Idaho agriculture's weakest spot—semiarid rangelands, where control is not practical because of difficult terrain and low return on investment. From there, it continually spreads to better land.

Biology and Ecology

Yellow starthistle is a member of the sunflower family (Asteraceae). This family includes many weeds, wild plants, ornamentals and crops. Closest relatives are the knapweeds, and other relatives are chicory, dandelion, safflower and artichoke.

Seasonal development and life cycle

Yellow starthistle is a somewhat winter-hardy annual. It normally begins growth after fall rains, although it will germinate any time the soil moisture and temperature are sufficient. At emergence, the cotyledons, or seed leaves, are oblong. The secondary leaves are longer and narrower; later leaves are lobed. In early spring, 7 or 8 lobed leaves emerge to form a rosette as the plant continues to increase in height and diameter. Early rosette stage plants are about 0.5 to 2 inches in diameter with 8 to 15 leaves while later stage plants maybe 6 to 8 inches in diameter with up to 26 leaves. In areas where the population is dense and crowding occurs plants have fewer leaves.

Yellow starthistle begins to bolt in late May and early-June, sending up a single stalk with branches tipped with a firm flower bud. During this spring growth period, dense infesta-

Figure 2. Yellow starthistle seedling.

Figure 3. In foreground, Alkar tall wheat grass (right) and Siberian wheatgrass (left) strips. Also see figure 10.

Figure 4. Flower and bud.

Figure 5. Seeds.

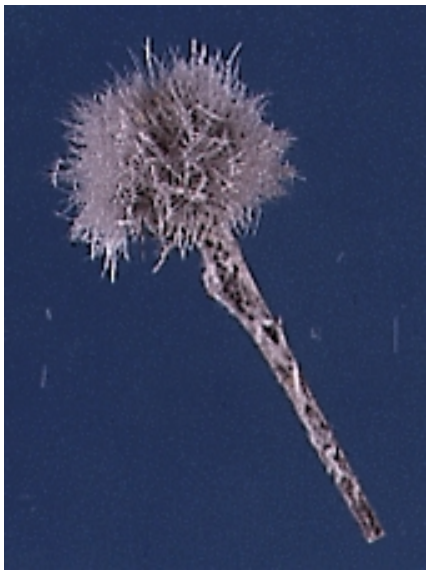


Figure 6. Seed head skeleton.

tions of yellow starthistle that inhabits southern exposures of steep canyons may be identified from a distance by their characteristic blue-green color (Fig. 3).

From mid-June to early July, each flower bud appears as a small swelling enclosed by shingle-like layers of bud scales called bracts. A soft yellow-green spine appears at the tip of each bract. The spine develops with the bud to eventually become 0.25 to 2 inches long forming a hard and sharp spine after the flowers fully open.

The flowering stage can be recognized from early July through August as bright dandelion-yellow flowers (Fig. 4). One of these flower heads may look like a single flower, but it actually is a cluster of tiny flowers as in a dandelion flower head. At this stage, the plants may be detected easily, but they are too mature to control economically. Plants usually mature at heights of 1 to 3 feet, but may range from 3 inches up to 6 feet. Extremely small plants can mature with an unbranched stem and one flower head; very large plants have many branches and may produce more than 200 flower heads. The plants are indeterminate in flowering habit and will continue to flower until frost if moisture is available. Seeds start to mature in the seed heads within 26 to 30 days after the buds open to show the first yellow petals.

Starting in early August and extending through September as the soil moisture declines, the leaves wither and dry, the bright yellow flowers fade, and the plants take on a straw-colored appearance. Seeds are of

two types, those with and those without a white, feathery plume that carries the seed a few feet in the wind or clings to clothing, fur, or feathers (Fig. 5). Seeds without a plume are dropped below the parent plant to replant the site. Plumed seeds tend to remain dormant slightly longer than plumeless seeds (Fig. 6). The light-colored seeds are mature and are ready to be scattered when the flower head dries to a tan color.

Large areas of yellow starthistle-infested rangeland are easily identified during September and October. Plants continue to dry and lose leaves, becoming skeleton-like and silver-grey by December. The flower head has lost most of the spines by this time. The resultant white, cottony heads and silver-grey stems are highly visible, persisting until mid-spring or until the plant disintegrates (Fig. 6).

Seeds at the soil surface begin to germinate with the onset of fall rains or warming temperatures in late winter and early spring, and the cycle is repeated.

Seed longevity

Yellow starthistle, like many destructive weeds, can produce several thousand seeds per plant. About 95 percent of the seeds produced are viable (Fig. 7). The plumeless and plumed lines indicate the smoothed average viability of 250 seeds placed in buried nylon packets at three depths in four replicates. The prediction interval shows estimated seed viability for 95 percent of the seeds in the buried packets based on probability and data variability. Most seeds produced in the current year will germinate and establish any time conditions are favorable. From 10 to 50 percent with an average of 20 percent of the seeds may remain alive after 1 year, and 1 to 2 percent percent can lie dormant for as long as 10 years.

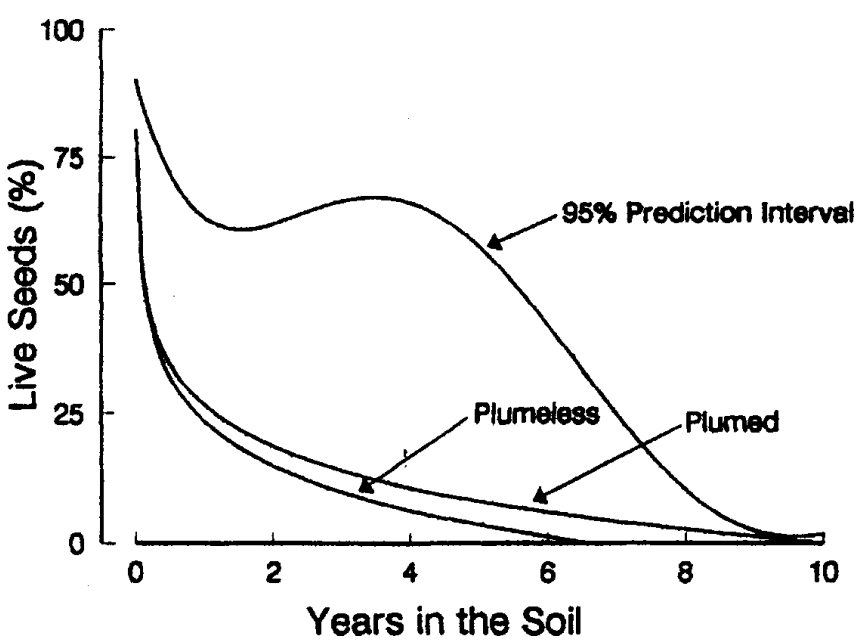


Figure 7. Seed longevity in the soil.

Dispersal

Research shows that 99 percent of the seeds from yellow starthistle plants fall within 10 feet of the parent plant. However, winds strong enough to move soil particles may move plumed yellow starthistle seeds for substantial distances. Strong thermal updrafts are common in canyon-lands during seed maturity, and may move seeds up very steep slopes.

Nearly any moving object may carry yellow starthistle seeds. The tiny seeds can be carried in very small amounts of soil. Soil normally clings to the feet of animals, and to vehicle tires, boots and clothing, moving great distances. The seeds become lodged in vehicles and equipment, clothing, and animal hair, and will temporarily adhere to nearly anything that is wet. Parts of mature yellow starthistle plants occasionally lodge in vehicles or animal hair and can be moved substantial distances. The common practice of recycling railroad ties and composting yard and animal waste from yellow starthistle-infested land for commercial resale moves the seed to unsuspecting landscapers and home owners. The yellow starthistle population in the Pacific Northwest increased 6,000 acres in one week when contaminated grass seed was planted on a soil stabilization project. Once an infestation becomes too large to stop seed production on all of the plants, it is not possible to prevent seed from moving significant distances away from the parent plants.

Introduction of seeds into an uninfested area can be greatly reduced by thorough, consistent

inspection and cleaning of animals, clothing, vehicles, construction material, and equipment to eliminate yellow starthistle seeds. You can reduce the potential of spreading seeds by 90 to 100 percent by spending a few minutes inspecting and cleaning clothing and equipment prior to leaving an infested site. Most people consider this impractical, time consuming, and expensive, so it is seldom practiced. Consequently, the steady spread of yellow starthistle into new areas is likely to continue for the foreseeable future.

Roots

Roots of yellow starthistle seedlings develop faster, and penetrate deeper, than those of grass seedlings. Roots continue to grow in the winter months whenever the soil temperature is above freezing, even though no apparent change occurs in leaves above ground. Yellow starthistle is, therefore, able to capture moisture, nutrients and solar energy before forage plants begin to grow. By the time the forages begin to grow, those resources maybe in short supply due to competition, and the forage species suffer.

Beneficial Uses

Yellow starthistle in the pre-flowering stage is consumed by cattle and sheep and other livestock. Yellow starthistle compares favorably in digestibility and nutritive value to good domestic forages when used before it begins to mature. However, it is not a desirable forage because of other aggressive and toxic aspects of the species.

Yellow starthistle is beneficially used for honeybee pasture. Research shows that flowers are very low in nectar production compared to many other plants used by honeybees. Nonetheless, the vast expanses of yellow starthistle-infested rangeland and the prolific flowering during early and mid-summer provide large amounts of honey. The bees are relatively safer foraging in rangeland than in cropland, because they are less apt to be exposed to insecticides when foraging in yellow starthistle. Unfortunately, seed production of yellow starthistle increases by more than 20 times when plants are visited by bees.

Control or eradication?

Control or suppression of yellow starthistle where the weed is widespread on pasture and rangeland is most effective when several proven control procedures are integrated into a management system. These management procedures offer suppression of yellow starthistle and other undesirable species together with enhancement of desirable forage species and soil fertility. Any management system that includes these elements will likely succeed while programs that do not consider these factors maybe doomed to failure.

Complete eradication of yellow starthistle on productive land maybe achieved if seed from outside sources is kept from the area, and if all proven control measures are applied in a timely manner. Complete eradication requires plant destruction (or removal) before they produce seed over a 10-year period to ensure that dormant seeds do not produce new seed-bearing plants (Fig. 6). The eradication plan should destroy all the yellow starthistle in the first five years. Routine inspection for new plants and control must continue every 4 to 6 weeks during the next five years. Eradication management should be used on small productive land parcels having isolated patches where management practices and monitoring are feasible. Small lot owners may readily adopt the eradication strategy while large scale land owners have found eradication logistically and economically unacceptable.

Short-term Control

Hand labor

Hand labor can be used to control yellow starthistle if only a few plants are present, even on large properties. Hand-pulling, shovel, hoe and various weed digging devices may be used effectively. Use leather gloves when handling the plants to prevent injury from the spines and reduce contact with plant material. Hand removal by pulling works, but should be used when the soil is soft. The plants should be large enough that they will not break, leaving the crown for regrowth. Digging and pulling requires diligence over time since the soil contains seeds from the previous year's plants. Hand removal is seldom consistent enough to retard the advance of yellow starthistle, but it is an appropriate procedure if used with sustained effort over time.

Cutting

Mowing or cutting yellow starthistle is seldom effective for long-term suppression, and will not eradicate the weed. Side branches stimulated to arise from shoot buds below the cut portion will produce additional flowers and seeds from those branches. Mowing after stems elongate above the cutting height of the mower may improve the appearance of the infested area and will reduce, but not eliminate the weed's seed production. Mowing will not prevent spread of yellow starthistle, so it does not comply with noxious weed law requirements.

Burning

Yellow starthistle population densities may be reduced, sometimes as much as 30 to 70 percent, and sometimes for as long as 1 to 2 years after a single, early-season burning. Without further suppression measures seeds of yellow starthistle, annual grasses and other weeds in the soil will germinate quickly due to the warmer, blackened, litter-free soil. Burning for yellow starthistle control is not recommended because of the risk of wildfire damage to nontarget areas, because of the risk of damage to perennial species, and because it generally does not reduce yellow starthistle populations. The principal benefit of a single burn is elimination of vegetative residue, which can facilitate grass planting and reduce the fuel load in infested sites.

A series of prescribed burns when annual grasses are dry, but before yellow starthistle flowers open, has been used to prevent yellow starthistle seed production in the Coast Range annual grasslands of California. Fire was used to burn the dry annual grass vegetation and seeds, but it scorched the yellow starthistle flowers enough to prevent seed development. After the third annual burn, perennial grass (purple needlegrass) was increased three-fold when compared to unburned sites and yellow starthistle was reduced 96 percent. This procedure has not been evaluated using annual grass species found in the Pacific Northwest. Delaying the fire until yellow starthistle is dry enough to burn allows the seeds of the annual grasses and some yellow starthistle seed to be distributed and escape the fire.

Fire is a temporary control since the remaining plant community did not prevent the original establishment of yellow starthistle at the site. Improving the plant community by planting and establishing desirable perennial grasses and forbs must be included with fire management. Annual grasses and yellow starthistle germinate and emerge quickly after the first and second burns. They may be controlled with foliar herbicides in late fall or late winter, before late winter or early spring grass planting. When this procedure is followed, better perennial grass stands may result after the burn.

Herbicides

Short-term control of yellow starthistle, as a part of long-term land renovation, can be achieved by using herbicides that are labeled for that use (see a current edition of the *Pacific Northwest Weed Control Handbook*). Repeated applications of short-residual hormonal-action herbicides are effective when applied in late winter or early spring when yellow starthistle is in the seedling or small rosette stage. These treatments only kills the current season's yellow starthistle plants, so it only suppresses yellow starthistle for about a year. Most sites will require the introduction of competitive perennial grasses to prevent reinvasion of yellow starthistle. In a few sites, the density of perennial grass is sufficient to allow a single herbicide treatment along with other good grass management practices for perennial grass vigor to return and dominate the site. The grass stand density necessary to be competitive depends on the grass species and potential productivity of the site. Vigorous perennial grass stands normally inhibit yellow starthistle population so retreatment with a herbicide is needed every 5 to 10 years, or even less frequently, if occasional surviving plants are removed by hand or spot spraying.

The main limitation of chemical control is that the most effective herbicides on yellow starthistle can be hazardous to certain other non-grass plant species. This can be illustrated in a study conducted to determine changes in plant species numbers and their frequencies of occurrence following a single herbicide application to a yellow starthistle infested range site. Data on occurrence were taken two months after herbicide application (Table 1). Herbicide rates for the project were in the normal use range. In the piclo-

Table 1. The effects of herbicides on species presence in a yellow starthistle community.

		Herbicide treatment[1]							
		Check	dicamba	2,4-D	clopyralid	picloram	imazapyr	metsulfuron	chlorsulfuron
		Use rate							
Common name	Scientific name	Plants present in 12 samples.							
Yellow starthistle	Centaurea solstitialis	12	9	12	3	1	0	12	12
Hairy vetch	Vicia villosa	10	0	5	0	0	0	6	6
Windgrass	Apera interrupta	9	12	12	10	10	0	7	9
Downy brome	Bromus tectorum	8	8	10	9	9	0	13	9
Tumble mustard	Sisymbrium altissimum	7	5	0	8	3	0	0	0
Clasping pepperweed	Lepidium perfoliatum	7	7	1	6	3	0	0	0
Catchweed bedstraw	Galium aparine	7	0	9	5	0	0	6	1
Speedwell	Veronica hederaefolia	7	9	3	9	10	0	1	3
Fiddleneck	Amsinckia retrorsa	6	0	2	8	0	0	0	0
Blue scorpion grass	Myosotis micrantha	6	0	0	12	0	0	0	0
Lamb's lettuce	Valerianella locusta	4	1	0	0	0	0	0	0
Rattail fescue	Vulpia myuros	4	4	7	12	8	0	6	7
Prickly lettuce	Lactuca serriola	3	0	0	0	0	0	0	0
Japanese brome	Bromus japonicus	2	0	2	4	4	0	2	2
Bur chervil	Anthriscus caucalis	1	3	1	0	0	0	0	0
Field bindweed	Convolvulus arvensis	1	0	0	0	2	0	1	3
St. Johnswort	Hypericum perforatum	1	2	1	3	0	0	4	0
Miner's lettuce	Montia perfoliata	1	2	6	7	5	0	0	0
Narrow-leaf collomia	Collomia linearis	1	0	0	3	0	0	0	0
Redstem filaree	Erodium cirutariium	1	0	5	5	0	0	3	0

[1]dicamba = Banvel, Clarity; clopyralid = Stinger; picloram = Tordon imazapyr = Arsenal; metsulfuron = Escort, Ally; chlorsulfuron = Glean, Telar.

ram treatments, yellow starthistle occurrence was reduced but the occurrence of miner's lettuce and speedwell increased. The percent occurrence of most broadleaf species tends to decline with the herbicide treatment, but this is dependent on selectivity of the herbicide. (Table 1). When used as directed by the label, herbicides used for yellow starthistle management can be used safely and effectively.

Annual applications of herbicides such as 2,4-D, clopyralid, or dicamba are effective for control of yellow starthistle when following the label instructions. For rangeland infestations that are not near herbicide-sensitive areas such as streams and rivers, home sites, orchards, gardens, or other ornamental or sensitive plants, longer-lasting selective herbicides, picloram in particular, are appropriate. Clopyralid, dicamba, and picloram are effective through the soil as pre-emergence herbicides as well as through the foliage of the weed.

Selective soil residual herbicides control the weeds long enough to establish competitive grasses or to allow recovery of suppressed grasses. Proper timing of herbicide application is critical. Foliage-active herbicides for range or pasture should be applied in late winter or early spring when the majority of yellow starthistle plants are in a small rosette stage (not more than 15 leaves), well before bolting. Long-residual herbicides like clopyralid and picloram remain active in the soil and may kill yellow starthistle seedlings for 18 months to 3 years. The longevity of these products depends on the herbicide, its

dosage and the environmental conditions. In most cases, follow-up applications are necessary to control escaped plants in treatment skips. A short-residual foliage-active hormone herbicide such as 2,4-D is effective and preferred where long-residual herbicides cannot be used. It must be applied more frequently than the long-residual herbicides. Dicamba will suppress yellow starthistle seedlings for a few weeks and has a longer residual than 2,4-D. Dicamba may be useful where only one or two herbicide applications are possible during the year. Users should refer to the specific herbicide labels for dosage, timing and precautions.

Regardless of the herbicide used, the initial treatment should be as early in the spring as practical to allow time to identify and apply follow-up application for treatment skips well before the bolting stage. Occasionally, fall and winter weather is too dry for yellow starthistle seed to germinate and emergence is delayed until spring. When these conditions occur, delay treatment until the main flush of germination occurs and seedlings have emerged. A single follow-up treatment about two weeks after treatment should be applied to plants escaping the initial treatment.

Treatment with a herbicide when yellow starthistle plants are in the bud or early flowering stage may greatly reduce the number of seeds produced and the proportion of viable seeds, but this is not cost-effective. It will not reliably destroy the plants unless the dosage is much higher than that necessary to kill plants in the seedling and rosette stages. The yellow starthistle stand may be somewhat less dense the next year, but the plants may be larger and more prolific because of the reduced competition. Herbicides that are applied in mid-summer, during dry periods, may degrade from sunlight and the hot summer temperatures may increase product loss through vaporization of the herbicide. This degradation prevents soil-active herbicides from persisting sufficiently into the fall to satisfactorily control fall-germinating yellow starthistle plants.

Regardless of the kind of herbicide, do not expect to rid your land of yellow starthistle with a single herbicide application. One application may reduce the population satisfactorily, but the effect will be temporary. Nonuniform application, germination of dormant seeds after the herbicide biodegrades, and adverse environmental conditions allow some plants to temporarily escape the treatment. Large areas with plants escaping treatment may require repeated broadcast applications. Small patches and isolated plants escaping the treatment can be spot sprayed with a backpack sprayer or hand-pulled.

Herbicide treatments alone as a management program usually fail because the treated areas do not have enough aggressive perennial grass to fill the space opened up when yellow starthistle plants are controlled. As a result, the land usually will become heavily reinfested with yellow starthistle in a short time if follow-up herbicide treatments are not used.

Grazing management to limit reinfestation is of utmost importance. Where the site is well populated with perennial grasses (60 to 80 percent ground cover), but suppressed by dense yellow starthistle, herbicide treatment must be followed by one year's grazing rest to allow the perennial grasses to recover from the effects of the yellow starthistle. Fertilization may stimulate grass production and improve its competition against weeds. The area may be grazed during the fall of the second year if the perennial grasses regain full development. In most cases it will require grazing be delayed 18 months or more to allow the grasses to establish and become competitive (See section on Costs). Therefore, use herbicides only if the yellow starthistle regains prominence.

Rotate herbicide families used for weed control on rangeland. Repeated use of highly effective hormone herbicides for yellow starthistle control has created a selection process for herbicide resistance plants. Two populations of yellow starthistle treated with the same herbicide family for eight successive years are now resistant to high doses of picloram and cross-resistance to other hormone type herbicides. The yellow starthistle in these areas are resistant to doses at eight times the normal use rate thus making the cost of control prohibitive with hormone herbicides. A high concentration application of these herbicides will cause the leaves of resistant plants to twist but the plants will still produce seed.

Herbicides recommended for yellow starthistle are listed in the current issue of the Pacific Northwest Weed Control Handbook. Also see CIS 1036, "Yellow Starthistle Management With Herbicides" for further information.

Biological control

Long-term yellow starthistle management for large land owners maybe best achieved with a biological control component in the vegetation management system. Biological control is any process that depends on living organisms that consume, parasitize, or otherwise suppress the weed such as plant competition. Living organisms currently showing most promise for reducing yellow starthistle populations are insects that focus for the most part on consuming yellow starthistle, and competitive plant species that compete for light, water, and nutrients. Use of grazing animals has been studied, but results are not conclusive. Fungi that attack the target plant species are under study and development, and may be important in the future.

Photo by John Connett

Figure 8. Bangasternus orientalis on yellow starthistle head.

Photo by John Connett

Figure 9. Eustenopus villosus female forming egg cavity.

Insects

Insects that feed and develop on yellow starthistle hold substantial promise for future control of the species. Since biological organisms or agents are expected to play a significant role in reducing yellow starthistle population in the future, state and federal agencies have imported them from Europe into the Pacific Northwest region following rigorous host specificity testing.

University of Idaho and USDA researchers are evaluating several insect species and fungi to assess their ability to reduce yellow starthistle populations. These insects are specialized natural enemies, and they are carefully selected to ensure that they do not affect organisms other than the target weeds. Although these biological control organisms show promise, success has not yet been widely demonstrated and many practical questions regarding site specificity must be answered before they can be fully incorporated into a management program. Biological control organisms will not eradicate

yellow starthistle infestations, nor will they totally prevent the spread of the weed. Since yellow starthistle is a seed-dependent annual, insects that feed on or otherwise destroy yellow starthistle seeds are expected to be effective.

Bangasternus orientalis (Fig. 8) is a beetle that feeds within the bud head of yellow starthistle. It was first released at many sites in the Clearwater and Salmon River canyons during 1984 to 1986. The beetle has established and spread throughout the yellow starthistle infested area. The beetle also was released earlier in California where it now destroys about 17 percent of the yellow starthistle seeds at the release sites. Increases in the beetle populations are expected to result in a measurable effect on the weed in the Western States. This beetle does not need to be distributed manually because it is a good flier and has found its way to nearly all yellow starthistle infestations in the Pacific Northwest. The weevils *Eustenopus villosus* and *Larinus curtus,* and two flies, *Chaetorellia australis* and *Urophora sirunaseva*, are all established in the Pacific Northwest. *Eustenopus villosus* (Fig. 9) promises to provide good control, but it is not a good flier, so it will probably require human redistribution to facilitate movement to disjunct yellow starthistle colonies.

Few weed species have been controlled satisfactorily with natural enemy organisms alone. Feeding by the biocontrol agents reduces the size, vigor and number of plants, so fewer seeds are available for germination. Other plants then can compete more successfully for light, water, and nutrients. All of these organisms together should eventually provide significant reductions of yellow starthistle. Information from Table 1 can be used to indicate the resulting species which may invade when yellow starthistle is removed from a rangeland site. None of the species in the list are desirable forages. Miner's lettuce and narrow leaf collomia would be considered components of pre-Caucasian types of vegetation in the steppe region of the Pacific Northwest, but the rest of the listed species are indicators of poor quality rangeland. Biocontrol agents reduce the weed's competitive ability, but will not change the plant components of the remaining community. Reducing yellow starthistle populations will allow something different to grow in its place; but they do not cause something better to grow in its place. What the ecosystem needs most of all is a defense against all invading weed species. Good perennial grass provides that defense, and where perennial grass has been reduced or lost, it must be rehabilitated or replaced. Using competitive plants and specialized weed parasites are key components of true integrated pest management. Consistent application of these and other successful management techniques will ultimately be the answer to control. Biocontrol alone will not solve the poor quality range problem of the Western States.

Grazing animals

Grazing animals utilize yellow starthistle and it is one of the few ways to realize economic return on rangeland. The management of grazing is critical to reducing the number of yellow starthistle plants, but the grazing process itself seldom results in suppression and long term reduction of yellow starthistle. Almost all classes of grazing animals will consume yellow starthistle if other forage is unavailable or inadequate. However, as stated earlier, horses are susceptible to the toxin in yellow starthistle and they should not be subjected to this toxic plant.

Certain grazing animals utilize yellow starthistle better than others. Goats tend to prefer broadleaved plants, including yellow starthistle, over grasses. Grazing reduces yellow starthistle leaf surface resulting in suppression of plant vigor and favors the development of competitive grasses. Sheep will graze yellow starthistle, but apparently they do not favor it over the available grasses. Yellow starthistle infestations are not reduced by sheep. Cattle and horses will graze yellow starthistle however they prefer grass so yellow starthistle growth is favored by these animals. If the grasses are mainly annuals such as downy brome, bulbous bluegrass or sixweeks fescue, animals will feed on yellow starthistle after the grasses are dry.

Young green yellow starthistle foliage in small amounts is much more digestible than grass and is a high protein source. However, studies

Figure 10. Alkar tall wheatgrass strip slowed re-invasion when compared to the Siberian wheatgrass strip.

with a related *Centaurea* species suggest that large quantities in a ruminant diet may inhibit digestibility. Yellow starthistle is more nutritious than grass until the time when spines have formed then its nutritive value is about equal to low-quality grass hay. Livestock weight gain is limited when grazing is limited to a yellow starthistle diet.

Competition

Management practices that promote a good stand of desirable vegetation is the basis of an effective, long-term weed control program, whether the weed is yellow starthistle or another species. Vigorous competitive grass or other vegetation is essential to maintain and enlarge a plant community's biological resistance to a yellow starthistle invasion. Management practices that stimulate desirable vegetation are indispensable since the grasses are effective competitors against all weeds, not just yellow starthistle. Desirable grasses add value as a forage and enhance the stability of a plant community.

For land that might be treated with a herbicide for suppression of yellow starthistle, grasses are more suitable than forbs because grasses tolerate exposure to the selective herbicides used for control. Even when grasses are used in a yellow starthistle management program, grazing and other stresses may reduce their vigor, allowing yellow starthistle to increase and dominate. In these situations, rehabilitative measures such as spraying, reseeding and deferred grazing must be used to allow reestablishment of a competitive grass stand.

Grasses are normally more competitive than forbs because they are well adapted to persist in environments that yellow starthistle can invade. Annual grasses such as downy brome or annual fescues do not adequately compete with yellow starthistle. Well-adapted perennial grasses, whether bunchgrasses or creeping grasses, resist weed invasion once they are established and well managed.

Suppression of yellow starthistle by plant competition is a proven, essential part of a yellow starthistle management program. Desirable species must immediately fill vacancies left when yellow starthistle is destroyed or suppressed or those vacancies will be filled by other undesirable species that await their opportunity. Once established, a vigorous stand of desirable, competitive forage species is the best defense against range or pasture deterioration because the stand retards or resists the invasion of all weed species (Figs. 3 and 10). The grasses will tolerate herbicides that must be used to provide rapid and complete (although short term) elimination of yellow starthistle.

If competitive plants are present in the infested site, the management objective should be to conserve and encourage them. If grass must be seeded, the transition from yellow starthistle to a competitive grass stand is more demanding. Grass seeding requires a substantial investment and success of a new seeding depends upon rain-fall as well as management.

Winter annual grasses such as bromes, fescues or medusahead are usually present at the site and will crowd-out seeded species even when yellow starthistle is controlled unless special management steps are followed. This may require late-fall application of a non-residual grass herbicide to control winter annuals just before seeding or it may require use of a residual herbicide that the seeded grass species can tolerate. Integration of control tactics is necessary for successful management. Futhermore, those management strategies will be site-specific; thus, requiring appropriate assessment of the infested lands.

Grass competition may be strengthened by increasing the utilization of nutrients and moisture in the complete rooting zone of yellow starthistle. Using tap-rooted forage legumes in a grass mix will help deplete resources normally available to yellow starthistle, but not short-rooted grasses. Alfalfa, lupine, and small burnett offers both increased competition and nitrogen fixation, but their inclusion in a management system will limit herbicide choices when further intervention is required.

Grasses to use for revegetation

The best grasses to use are those that are best adapted to a target site. Obviously, they must be appropriate for the land's expected use. To determine which of the grasses are most appropriate to a site, contact the Cooperative Extension System office or Soil Conservation Service office in your county. In general, where yellow starthistle is well adapted, intermediate wheatgrass, tall wheatgrass, pubescent wheatgrass, tall oatgrass, and bunch-type fescues are adapted and competitive against yellow starthistle.

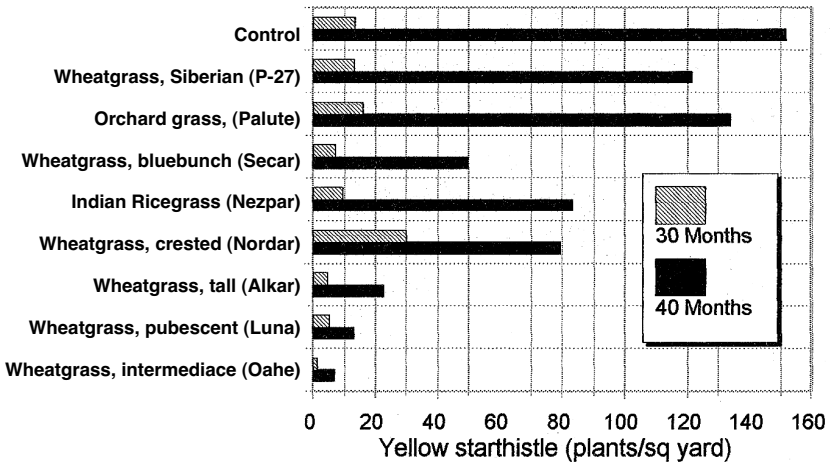


Figure 11. Suppression of yellow starthistle re-entry by grasses in a rangeland site with moderately deep soils. The land was prepared by fall tillage and planted in early spring with a single application of picloram after grass emergence. The bar graph shows the amount of yellow starthistle that reestablished 30 and 40 months after planting. Also see Figure 10.

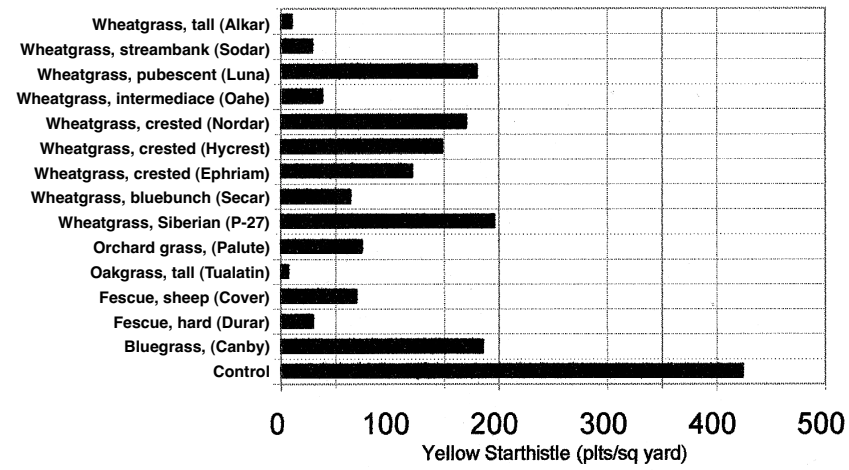


Figure 12. Resistance of various grasses to yellow starthistle invasion five years after planting in a moderately productive site. The semiarid site was tilled in the spring, grasses planted, and treated after emergence with a single application of clopyralid.

For sites that have shallow soils or inaccessible for renovation operations, such as steep canyonlands, pasture yield should not be the primary expectation. Instead, ecological stability should be the goal in order to prevent weed invasion. In such circumstances, bunch-type fine fescues such as sheep fescue, hard fescue or Idaho fescue should be considered. These grasses develop extensive root systems that prevent roots of seedling yellow starthistle from establishing. Although the grasses are slow to establish, they can also persist under semiarid conditions and provide significant ecological stabilization and are competitive against yellow starthistle.

For sites with moderate soil depth and some potential productivity as rangeland and on land that is accessible with tractors and tillage equipment, grasses of higher potential yields should be considered (Fig. 11). These may include sod-forming species such as intermediate or pubescent wheatgrass. These grasses are able to spread within the stand using rhizomes, thus successfully competing against all annual grasses and weedy forbs such as yellow starthistle.

Where soil productivity is high and precipitation is generally above 16 inches per year or moisture is available from subsoil flow such as at the base of steep slopes, tall oatgrass, tall wheatgrass, and streambank wheatgrass may be suitable (Fig 12). These sites are typically potential crop land fields that would produce marginal to fair yields as crop land but would be an excellent pasture. Competition between these grasses and yellow starthistle appears to be based on limiting light to seedling yellow starthistle plants. Grazing without allowing time for grass recovery to provide sufficient shading in the fall and spring may reduce the competitive effects of these grasses.

Do not plant a species that has not been shown to be adapted to the site by University or Soil Conservation specialist. Some species, such as buffalograss, grama grasses, perennial bromes, bluegrass, and the bluestems are useful in the Great Plains where summer precipitation is substantial, but generally perform poorly in arid and semiarid areas of the Pacific Northwest, where dry summers prevail. High-yielding forage grasses such as smooth brome, meadow brome, timothy, orchard grass, redtop, creeping and tall fescues, and big bluegrass may establish on a yellow starthistle-infested site, but are not very competitive in a typical yellow starthistle-infested site. University of Idaho tests have shown that high yielding forage grasses tend to disappear within two to three years after yellow starthistle returns to the site.

Planting grass successfully on rangeland/pasture land

Principles of planting

The keys to successful grass plantings are these:

1 Plant early enough for the grass to develop to the tillered stage so that the grass plants can with stand summer drought conditions.
2 Place the seeds in firm contact with the soil.
3 Cover the seeds to keep the seeds moist until the roots are well into moist soil as the upper soil profile dries.
4 Protect the seedlings from destruction or consumption by animals, diseases, insects or weeds.

When to plant

Whether you plant in late fall or early spring, the key is to plant grass when the prospect of a long period of moist soil is likely. This may be during late fall after fall rains thoroughly wet the soil profile, or it may be in late winter or early spring after a wet winter. Good soil moisture is necessary for successful grass establishment.

Preparing the site

If possible prepare the site as if you will be planting crop like small grains. This will provide the best chance for establishing the grasses, but this is not possible for most sites. Alternatively, the site may be planted using a no-till method. In the late fall, there is an optimum planting period between the start of the fall rains and frozen ground and early spring between frozen ground and spring green up when the soil profile is moist but not too wet for the planting equipment operation. The field should be sprayed before planting with a non-residual, foliar-active herbicide that effectively controls both grasses and broadleaf plants. The seed should be drilled into the plant residue from the previous season using a grain drill with the disks fully extended and the drag chains or press wheels removed. The residue keeps the disks near the

Table 2. Terrain and vegetation types infested with yellow starthistle in northern Idaho.

	Slope (percent)				
Vegetation type	All Slopes	Large infestations 0-20	Large infestations 21-40	Small infestations 0-40	Large infestations >40
	(percent of Land)				
Conifer	4.4	0.3	0.1	1.0	3.0
Conifer-shrub-grass	16.0	2.0	1.0	3.0	10.0
Shrub-Grass	54.6	11.6	4.0	18.0	21.0
Grass	25.0	7.0	2.0	8.0	8.0
Total Vegetation	100.0	20.9	7.1	30.0	42.0

"Small infestation" is defined as 6 acres or less.

surface and the disks tend to make a 0.75 to 1 inch opening so the seeds have good soil contact. Closure of the furrow created by the disks is not necessary for the seeds to germinate and the grasses to establish.

Even when grass seed is planted properly, establishment of a satisfactory stand is likely to fail if nothing is done to suppress the weeds during the first season when the grass is establishing. Downy brome, sixweeks fescue, yellow starthistle, annual mustards, and many other annual weeds will out-compete young seedlings of perennial grass. Protection of the grass seedlings during the establishment stage can be accomplished by treating the growing weeds with a non-residual herbicide such as glyphosate (Roundup) prior to planting that is effective on both annual grasses and broadleaf annual weeds. This is best done after the annual grasses emerges after fall or early spring precipitation, about two weeks before planting.

How to plant

Plant with a seed drill if the terrain will allow operation of tractor-drawn equipment. If the terrain is too rugged for such equipment, broadcast the seeds at triple or more the normal drilled seeding rate, and herd livestock over the ground until hooves have impacted 90 percent or more of the soil surface. Soil moisture needs to be near saturation to improve hoof action when working the seed into the soil surface. Though hoofmarks may not be visible where vegetation is heavy, hoof coverage is sufficient if the litter is broken up on more than 90 percent of the land surface. Expect no more than about one tenth of the seeds developing to the seedling stage. This is an imperfect means of getting seed-to-soil contact. Nevertheless, it is far better than simply broadcasting the seeds.

Economic considerations

Prevention and inspection are the most economical management system for reducing the rate of yellow starthistle spread. Knowing where equipment, soil, plant material, animals, and construction material comes from before allowing it on uninfested property will reduce the chance of weed introduction and long-term management costs. Requiring the cleaning or containment of contaminated material to specific sites on the property can reduce treatment areas to manageable levels. It is more cost effective to exclude yellow starthistle than to try to suppress it after it is established.

Herbicide spraying to control yellow starthistle is economically impractical for most of the steep canyon-land in the Pacific Northwest. Eliminating yellow starthistle without further renovation and long-term management only opens these lands to infestation by other weeds. Yellow starthistle should be eradicated completely with herbicides where infestations are small or new to an area. Where

the infestation is already extensive, spending money for removal of yellow starthistle may be economically feasible only where the land is productive and where it can be rehabilitated or renovated. The land that will yield the highest return on investment is land accessible with ground equipment. Such ground normally has the most productive soil. Renovation or establishment of aggressive perennial grasses is biologically valid, economically efficient and ecologically necessary on those highly productive sites.

How much infested land can be renovated?

The most economical and successful method of renovating infested land is based on using conventional agricultural equipment. University of Idaho studies of yellow starthistle infested land in northern Idaho show that 58 percent of the infested land regardless of the vegetation type has slopes ranging from 0 to 40 percent (Table 2). These slopes can usually be negotiated with agricultural ground machinery, except where trees or rocky conditions prevent equipment operation. Tree and tall shrub areas account for less than 8 percent of the infested area with a slope appropriate for ground equipment. This would suggest 50 percent of the land infested with yellow starthistle could be renovated with ground equipment, but the proportion of ground too rocky to accommodate cultivation and seeding equipment has not been assessed. If half of this land is sufficiently free of excessive rocks and other barriers, more than 50,000 acres of the currently infested land could be managed with ground equipment.

Where ground equipment cannot be operated, the additional costs, risk, and uncertainty of successful management with herbicide and grass establishment are not justified on a large scale. Herbicides and fertilizers can be applied by aircraft, but reseeding grasses on the rough terrain by broadcast techniques without a means of covering the seed has not been consistently successful. Land that is accessible with ground equipment normally has soil sufficiently deep to be reasonably productive. Such land offers the likelihood of the best return on investment, and should be the priority areas for intensive management. Where steep land has a sufficient residual stand of grass, even though the plants may be small and weak, fertilization, in combination with a selective herbicide, may rehabilitate the grass stand sufficiently to return a profit.

Why spend money when there are bugs?

Artificially reducing the number of yellow starthistle plants to acceptable levels (a few plants per acre) with periodic herbicide treatments and establishment of competitive grasses will enhance the action of the established biocontrol agents. Biocontrol agent populations must increase to the point where each head is visited by the agent. Reducing yellow starthistle numbers will cause the biocontrol agents to focus on the remaining plants. The maximum productivity of the land and ecological stability could be hastened sooner during the transitional move from yellow starthistle dominance to a minor role in the ecosystem.

Past experience has shown that removal of yellow starthistle will allow undesirable annual grasses and other noxious weeds to establish on the site (See Table 1). Most sites do not have sufficient native perennial species to reestablish as the dominant portion of the plant community. Without establishing perennial grasses, forage production on the site could be reduced by 20 to 50 percent and the grazing season shortened by 2 to 3 weeks with the loss of yellow starthistle. The remaining annual grass community will be invaded by one or more other weedy species established adjacent to or within the current yellow starthistle populations. The establishment of competitive grasses to improve rangeland ecosystems breaks the weed invader cycle of weed population controlled by biocontrol agent then a new weed problem and new search for a control agent.

Costs

A land owner should conduct a complete land survey to map the locations of yellow starthistle as a starting point for developing a management plan. After surveying, start the renovation process with a demonstration size project (5 to 50 acres) to test the management plan for site specific variability. Tactically, it is better to start with the newest

infestations with scattered plants and work toward the oldest populations having the highest plant density. The strategies described in this bulletin are effective, but require significant economic inputs and labor. Herbicides can be applied with an agricultural field sprayer, which in some cases can be rented from fertilizer dealers for $5.00 to $15.00 per acre. A hand pump sprayer for spot spraying can be purchased for between $25.00 and $50.00 depending upon the quality desired. A typical hand pump sprayer should last from 5 to 10 years so the annual real cost will vary from $3.00 to $6.00 per year. For large areas, helicopter applications may be made at costs ranging from $10.00 to $12.00 per acre.

Herbicide application (includes chemical, equipment, and time) for yellow starthistle control typically cost between $25.00 and $55.00 per acre annually. Labor and materials for spot spraying to control occasional isolated plants or colonies are included in these costs. The cost of renovating or rehabilitating yellow starthistle-infested land in an integrated program for sustainable land management will vary with the specific site, but is normally between $60 and $80 the first year. Under appropriate management thereafter, costs are only those associated with maintaining vigorous, productive grass stands.

If horses are pastured on infested lands, additional care should be taken to prevent yellow starthistle from becoming a significant part of the horses' diet. Horses can be excluded from yellow starthistle areas with electric fencing, costing approximately $.30 to $.60 per linear foot of fence for 1,000 feet or more, depending on number of wires, distance between posts, length, terrain, labor cost, kind of material used, and other factors.

Side benefits of reclaiming infested land

The benefits of long-term yellow starthistle control may include control of other weeds that are susceptible to the same practices that control yellow starthistle. If management practices are directed at the fundamental causes of the yellow starthistle problem, then invasion by other weeds, some of which can be worse than yellow starthistle, will be minimized. The landowner should take such other benefits into account when comparing costs and benefits.

The practicality of range renovation depends on the likelihood of a satisfactory financial return over the long term. Idaho has enacted laws for the control of noxious weeds to help protect citizens from outside sources of those weeds. Idaho law classifies yellow starthistle as a noxious weed. This means it is the legal requirement of each landowner to control yellow starthistle on land that person owns or controls. However, it has become so widespread that portions of some counties have been declared exempt from the requirement to control it.

Additional information on the Internet.

The University of Idaho has a yellow starthistle web page at http://soils.ag.uidaho.edu/yst. The site has a complete literature review, pictures, and video of biocontrol insects and symptoms of chewings disease.

The University of California also has a yellow starthistle site located at http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn003.html

Additional references

CIS 1020 Yellow Starthistle Management for Homeowners

CIS 1025 Yellow Starthistle Management for Small Acreages

CIS 1036 Yellow Starthistle Management With Herbicides

Pacific Northwest Herbicide Handbook.

http://soils.ag.uidaho.edu/yst

http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn003.html.

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