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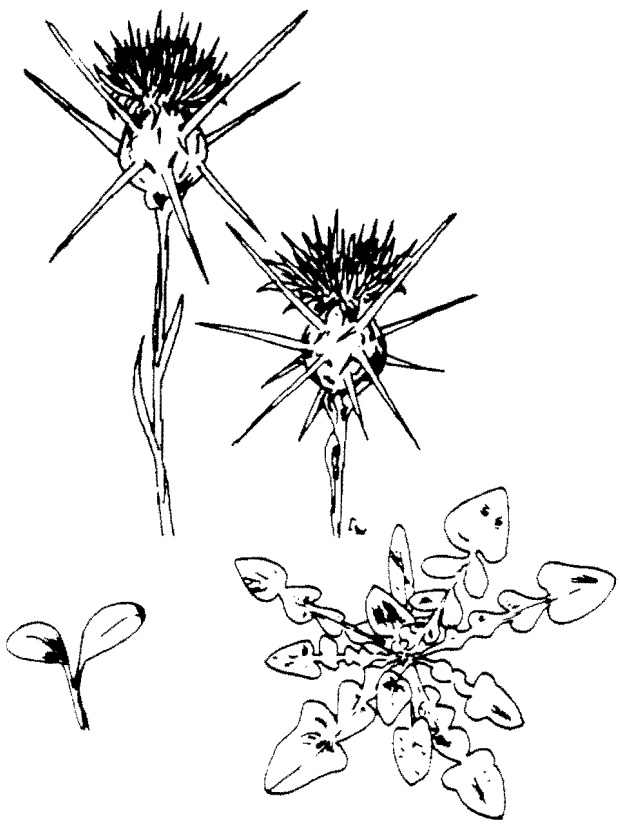
Yellow Starthistle Control

C.D. Thomsen, W.A. Williams, M. Vayssieres, and F.L. Bell

Yellow starthistle, *Centaurea solstitialis*, is a plant of Old World origin that probably arrived in California in the mid-1800s as a contaminant in alfalfa seed. Since its accidental introduction, it has steadily spread and now inhabits about 8 million acres statewide (Maddox and Mayfield 1985). It is one of California's worst noxious weeds, infesting parks and rangelands, pastures, hayfields, orchards, vineyards, roadsides, and irrigation banks. The presence and tenacity of starthistle on these lands has led to increased vegetation management costs and many inquiries on methods of control.



Life Cycle and Plant Description

Understanding yellow starthistle's biology is basic to developing a successful control program. Starthistle has a very long life cycle for an annual plant. Germination is initiated by autumn rains, but plants mature long after most other annuals have completed their life cycle, sometimes not completing their life cycle until the following fall or winter. The seedling stage is the most difficult time to identify the plants. One way is to locate seedlings under last year's skeletons. The winter and spring rosettes produce many deeply-lobed leaves. The size, number, and lobing pattern of the rosette leaves are variable, but a good diagnostic character is the large, triangular lobe at the tip of each leaf. In general, the rosettes tend to grow close to the ground in open places but they assume an upright habit at high densities.

During May and June the plant 'bolts' and sends up elongated stalks that produce the spiny flower heads. The grey- to bluish-green stems of the mature plant are ridged and widely branched, and the entire plant is covered with soft, appressed hairs. The bracts that surround the bright yellow flowers produce the characteristic rigid spines. The seed maturation stage can be recognized by the loss of the bright yellow pigment that characterizes the younger flowers. At this stage the seeds mature quickly. Two types of seed are produced. The lighter-colored seeds are located in the central (disk) portion of the flowerhead, contain short bristly hairs (pappus), and disperse quickly after maturity. Darker seeds occur in a circle around the disk seeds, usually lack hairs, and persist in the flowerhead until harsh weather or other disturbances break them up. After dispersal seeds become part of the soil's "seed bank" where they remain until conditions become favorable for germination, or are eliminated through natural means.

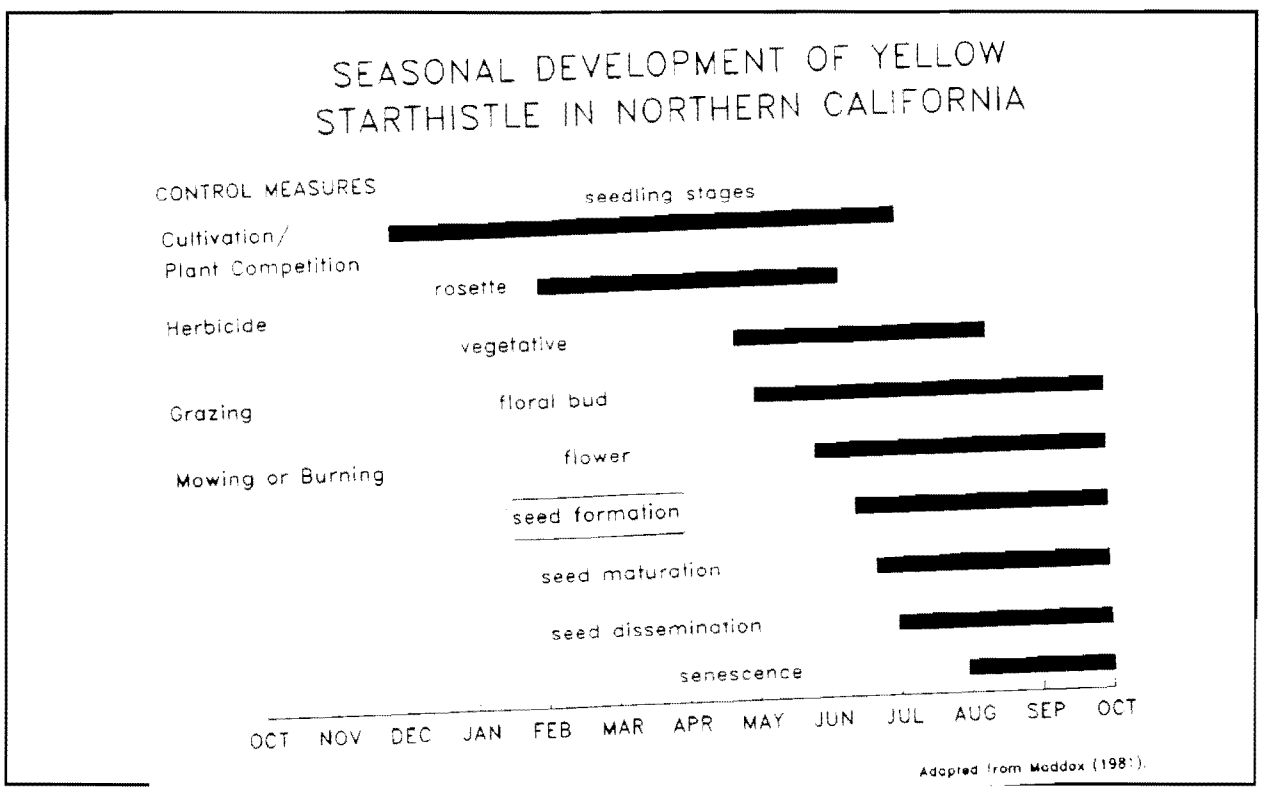
The number of seeds produced by individual plants varies widely according to environmental conditions and genetic factors. In a study of starthistle populations from Hopland, Woodland, and Concord, Maddox (1981) reported a range of 700 to 10,000 seeds per plant. Thomsen (unpublished data) followed an individual plant that had been sprayed with an herbicide during the bolting stage. The upper portion of the plant died back but regrew vigorously the next growing season from the taproot and produced an estimated 170,000 seeds.

Control Considerations

Controlling yellow starthistle on infested lands will require a systematic and persistent effort that may take many years. In many cases it will be an ongoing land management activity that will need to be continued on a more or less permanent basis. Various approaches can be taken, but the degree of control possible will depend on the size and density of the infestation, terrain, tools or equipment available, and planned use for the site.

When planning a control program one should decide if the aim is to **eradicate, manage,** or **contain** yellow starthistle. Eradication is the elimination of starthistle from the site, and requires that all seed production is halted and the seed bank in the soil from previous years is depleted. Eradication of large infestations is not practical but small infestations often can be successfully eliminated with diligence. Large infestations can usually be managed in ways that reduce starthistle to tolerable levels. Suitable management aims are to decrease plant densities, seed production, or plant height and canopy size, or use it as a feed resource for ruminants. Containment is attempted by delineating boundaries around large infestations and concentrating control efforts on the smaller patches that exist outside of the contained areas. By controlling isolated plants or small patches that are the "pioneers" of new infestations, the larger infestation is contained and the likelihood of invasion into new areas is reduced. As information and experience is gained from controlling small outlying infestations, better decisions can be made about whether larger areas can also be successfully controlled.

Timing control efforts to various stages of plant growth is essential. Figure 1 suggests the timing of some control measures according to specific stages of starthistle growth. Some measures can be used during several growth stages, but all of them should occur before seed set. The duration of life cycle stages depicted by the bars will vary considerably due to weather patterns, site differences, and genetic variation. Thus, on-site monitoring is necessary to determine exactly when a particular stage is occurring and control activities should be adjusted accordingly.



Control Methods

The methods of control include mechanical (tillage, mowing, and removal with hand tools), biological (insects, livestock grazing, and plant competition), fire, chemical, and prevention. In general the most effective control is achieved when two or more methods are used in combination. The methods discussed below are based on research, established principles of weed control, and anecdotal information. Research is incomplete, but studies are underway to fill some of the information gaps.

Mechanical Methods. Cultivation with appropriate tools as the seedlings emerge after autumn rains is an excellent means of removing young plants. On sites where irrigation is available, infested areas can be pre-irrigated prior to autumn rains and then disked to remove germinating seedlings. If cultivation is repeated after rains begin and a new flush of germinating seedlings has emerged, the seed bank can be reduced in a short time. When cultivation is done in the spring, plants will have well developed taproots and tillage should be deeper. Any tillage will also bring deeply buried seeds to the surface where they will have more favorable conditions for germination. If follow-up measures are not taken to also remove these seedlings, the infestation could get worse.

Mowing is a useful method for managing yellow starthistle stands, provided it is well-timed and repeated one to two times. Mowing will be most effective when soil moisture is low and no irrigation or rainfall follows. Under low soil moisture conditions a single mowing may be sufficient, but plants should be monitored for regrowth and mowed again if significant growth and flowering occurs. In most situations, one or two "follow-up" mowings will be necessary and should be done once flowering resumes, approximately four to six weeks later. Research at the UC Agronomy Farm demonstrated that mowing during the early flowering stage (before seed formation) reduced canopy size, seed production, and live plant density when compared to controls (unmowed) and plots mowed at earlier stages of development. Mowing too early appears to encourage its growth.

Ideally, all mowing should be done just prior to seed formation. Flower pigmentation is a good way to monitor whether seed development has commenced. When the flowers are bright yellow and have not begun fading, seed maturation has not occurred. If in doubt open a flower and check for mature seeds. Mowing after seeds have been produced removes the spiny canopies but does not diminish the seed bank and may aid in seed dispersal.

Manual weeding with hoes, weedeaters, or scythes is often a practical way to control small infestations or is useful as an adjunct to other methods. Hand-held equipment can be ideal for spot weeding plants that survived from other weed control activities.

Biological Control

Biological control involves the use of any biological organism such as insects, livestock grazing, and competitive plants that aid in starthistle suppression.

Insects

Several insects are being evaluated to determine their effectiveness in controlling starthistle populations. Field releases have been made throughout the state and some candidates appear promising, but additional time is needed to assess the long-term effects of these biocontrol agents.

Livestock Grazing

Controlled grazing has been demonstrated to be an effective method for managing large stands of yellow starthistle in annual grassland (Thomsen et al. 1993). Livestock will graze yellow starthistle before it becomes spiny, and studies have shown that it is an acceptable component of a **ruminant's** diet (Cordy 1978; Thomsen et al. 1989). Over a period of several years cattle, sheep, and goats were tested separately as biocontrol agents in densely infested grassland using intensive grazing management, i.e., high stocking densities and short grazing periods, timed to specific stages of starthistle development. Grazing while starthistle was in the rosette stage (March through April) did not suppress starthistle, but grazing during the bolting stage (May through June) reduced plant densities, height, and seed production. Grazing during the rosette stage favored yellow starthistle relative to other herbaceous vegetation. Along with yellow starthistle, neighboring plants were also defoliated, and the competition they provided was largely eliminated, since starthistle's ability to regrow following defoliation was much greater than the associated vegetation. When grazing was deferred until bolting, most other associated annual species had a chance to complete their life cycle and produce seed. Animals selectively grazed starthistle since it was still green and made use of it as a forage. Since most defoliated plants recovered quickly animals were brought back to the paddocks one to three times at about two week intervals. The

actual number of grazings required for suppression varied according to rainfall patterns and soil moisture levels.

Grazing yellow starthistle should not be attempted with horses. Prolonged ingestion by horses (86-200% of the horse's body weight) can lead to a fatal nervous disease called equine nigropallidal encephalomalacia or "chewing disease" (Cordy 1978). Horses are the only animal known to be affected by this disease, most cases occurring during October/November or June/July. Donkeys and mules are probably susceptible, but there are no documented poisonings (Fowler, per. comm.). The majority of cases that have been reported are with horses that are under two years old.

Plant Competition

Establishing competitive plants such as well-adapted grasses, legumes, or other appropriate plant materials should be considered as part of any control program. If starthistle is controlled, but the ecological niche that it occupied remains unfilled, reinvasion by starthistle will be easier or invasion by another undesirable species is likely. In most cases, a two-step approach is effective with some initial control work done prior to seeding desirable plants as the first step. Using a no-till drill allows seeding without turning the soil, and helps to keep deeply buried starthistle seeds form germinating.

The choice of plant materials should reflect the site conditions, type of management required to establish and maintain the plantings, and planned use of the site. If a large and potentially costly seeding is planned, some initial on-site small scale plantings should be done to evaluate which plants are best suited for your site and whether they are truly competitive against starthistle under the prevailing land use.

Both annual and perennial grasses have potential to compete against starthistle but will be most effective when combined with other methods such as a broad-leaved herbicide application. The timing of rainfall has an important influence on the competitive outcome. If late-season rains (during April through June) recharge soil moisture, starthistle will be favored. Since most annuals complete their life cycle long before starthistle, there will often be sufficient soil moisture remaining to support starthistle growth. Also, starthistle has a long taproot that grows much deeper than annual grasses, so it can obtain soil resources even in dense stands of grass. Nevertheless, if grass stands are dense and tall, competition for space and for light can be a contributing factor that helps suppress starthistle.

Most dryland perennial grasses will require at least two years to gain enough stature to provide competition and dense stands are required. Once established, some perennial grasses do have late spring and summer growth similar to starthistle, and with their vigorous root systems there is greater potential to remove soil moisture that would otherwise be used by starthistle. However, perennial grasses should not be expected to suppress starthistle when grazed by livestock unless they are part of a well-managed irrigated pasture.

Vigorous stands of annual legumes have the potential to suppress yellow starthistle. Drake (per. comm.) reported that a dense stand of rose clover Trifolium hirtum eliminated yellow starthistle in a Siskiyou County trial. Lana vetch Vicia villosa ssp. varia, a vigorous and sprawling vetch that forms a dense spring canopy has been reported to suppress starthistle (Roan, per. comm.). Other annual legumes such as some subterranean clover cultivars, have also been observed to suppress starthistle, particularly when combined with mowing or grazing. Research to examine this more closely is underway, supported by UC IPM. To obtain competitive stands it is advisable to use high seeding rates and to make sure that the seeds are properly inoculated with the host-specific nitrogen-fixing bacteria, Rhizobia spp. Fertilization with phosphorus or sulphur should be considered on range soils since they are often deficient in these nutrients.

Prescribed Burns. In some situations prescribed burns may be an appropriate management tool. The best time to burn is probably the same as for mowing, when plants are in the early flowering stage just prior to seed formation. Since starthistle is still green during this period, there must be enough dry biomass from other annual plants to carry a fire. Research using prescribed fire is being conducted at Sugarloaf Ridge State Park in Sonoma County, but it is inconclusive at present. Prior to conducting a burn on small acreages your local fire station should be contacted to obtain information on safe practices, designated burn days, and permits. For large acreages, the California Department of Forestry and Fire Protection Vegetation Management Program may offer some assistance and cost-sharing, particularly when the burn is part of an overall vegetation management plan that reduces the fire hazard of an area.

Chemical Control. There are many types of herbicides available, most requiring a permit from your County Agricultural Commissioner. If you are not familiar with herbicide use, refer to UC

Cooperative Extension publication No. 1919, *Selective Chemical Weed Control* for specific information (Ashton 1987). Before using any chemical, carefully read and follow precautions on the label. Like any other control method, the use of herbicides must be properly timed and more than one application per growing season may be necessary. Interference from surrounding vegetation might prevent uniform application and leave some starthistle unaffected. Another complicating factor is the successive germination in starthistle populations that occurs long into the growing season, often associated with rainfall. When herbicides are applied before all germination has occurred new seedlings will emerge and develop into adult plants. Foliar-applied, postemergent herbicides are most effective when temperatures are warm, soil moisture is high, and plants are actively growing. Post-emergent herbicides are most effective in seedling and rosette stages prior to any bolting.

Non-selective herbicides, like glyphosate, are effective for spot treatments. However, since glyphosate kills nearly all other vegetation, treatment with this chemical is not usually suited for use over large areas. Broadleaved herbicides such as Banvel, triclopyr, or 2,4-D will help control yellow starthistle and leave grasses unaffected. Care should be taken because these materials will also partially control legumes and other broadleaf plants that may provide competition against starthistle or may be useful to the ecosystem by providing soil cover, forage, biological diversity, or wildlife habitat.

Broadcast spraying in an infested area is not always necessary. Starthistle stands are often patchy and known starthistle areas can be marked with irrigation flags months before spraying and then specifically targeted at the proper time. The grey starthistle skeletons with heads resembling Q-tips that remain in the winter from previous growth are also good markers for locating patches of new seedlings.

Prevention. Preventive weed control measures consist of preventing the introduction or spread of starthistle to uninfested areas. As in containment programs, this includes detection and control of "pioneer" plants before they go to seed along roadsides, in fields, pastures, etc., and develop into larger infestations. Because spot occurrences and small colonies seem harmless, the tendency is to overlook them; however, this is the way most large infestations begin. Even though yellow starthistle is widespread, there are still many areas where it is adapted but has yet to invade or fully establish.

Combining Control Methods

The most effective way to control yellow starthistle is to use a combination of control methods. There are many possible combinations that can be used and tailored according to the site. On arable land good control of starthistle is obtained by using a combination of cultivation, herbicides, irrigation, and crops. On pastures the use of adapted plant materials combined with controlled grazing, well-timed mowing, or herbicides can lead to reduced populations. Perennial grasses in combination with herbicides, cultivation, and burning have been used effectively to suppress starthistle in drainage ditches, along roadsides, and on the borders of agricultural lands (Brown, Bugg and Anderson 1993.). These researchers are using a phased approach to vegetation management of rural landscapes. They begin with intensive weed control to reduce the soil's seed bank. Grasses are planted and herbicides are still used but are reduced as the deep-rooted grasses become well-established and competitive. When herbicide use subsides, broad-leaf plants such as lupines, poppies, and other native forbs are incorporated into the system. The investigators view this not only as a means to control weeds, but also to create wildlife habitat for game and nongame species, improve the aesthetics of the rural landscape, integrate biological diversity onto agricultural lands, and reduce the $40,000 a year ($100.00 per mile) spent on roadside weed control in Yolo County (Anderson 1993; Bugg, et al., 1991). These are a few of the many possible combinations of methods for controlling starthistle. But regardless of what methods are used together, effective long-term control requires that 1) seed production is halted, 2) plants emerging from the seed bank are eliminated, and when possible that 3) other, more competitive plants be permanently established that fit in the ecological niche once filled by starthistle to prevent reinvasion and to suppress other undesirable species.

Discussion

Although yellow starthistle is a troublesome weed, it does have some useful properties. Starthistle is a valuable source of summer nectar for bees, and honey produced from it of premium quality. Yellow starthistle's early and late-season growth, palatability, and resilience make it a useful forage plant to ruminant animals before it becomes spiny. In nutritional studies, crude protein levels were recorded from as high as 28% in the rosette stage to 13% in the bolting stage. At one site during bolting starthistle was estimated to exceed 4,000 lbs/acre of dry

matter in early June. Starthistle provides food and cover to wildlife, especially insects, small mammals, and some birds. As a colonizing species, it rapidly covers and helps stabilize unprotected soil.

But, despite these qualities, yellow starthistle remains a significant pest for many ranchers, landowners, and resource managers. Starthistle's invasiveness, stout spines, and hedge-like stands make controlling it a necessary task. Yellow starthistle will continue to increase statewide and is likely to be particularly prominent in years with abundant late-season rainfall.

Some ongoing research that we are involved with or aware of include timed mowing experiments and seed bank studies at the UC Davis Agronomy Farm; combining subterranean clover establishment with sheep grazing and mowing at the Bio-integral Resource Center near Winters; using perennial grasses along roadsides in Yolo County; prescribed burning and timed mowing at Sugarloaf State Park, Sonoma County; and biological control with insects and rusts at USDA-ARS, West Regional Research Center, Albany, California and at the Division of Biological Control, California Department of Food and Agriculture.

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