SPECIES: Centaurea solstitialis

INTRODUCTORY

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FEIS ABBREVIATION:
CENSOL

SYNONYMS:
No entry

NRCS PLANT CODE [155]:
CESO3

COMMON NAMES:
yellow starthistle
yellow star-thistle

yellow star thistle
St. Barnaby's thistle

TAXONOMY:
The currently accepted scientific name for yellow starthistle is *Centaurea solstitialis* L. (Asteraceae) [46,49,55,56,65,66,70,88,107,127,141,158].

LIFE FORM:
Forb

FEDERAL LEGAL STATUS:
No special status

OTHER STATUS:
As of this writing (2002), yellow starthistle is listed as a noxious weed in at least 11 states and 2 Canadian provinces. See the Invaders or Plants
databases for more information. The California Exotic Pest Plant Council lists yellow starthistle as one of the most widespread and invasive wildland pest plants in California (CalEPPC).

DISTRIBUTION AND OCCURRENCE

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GENERAL DISTRIBUTION:
Yellow starthistle is native to southern Europe and western Eurasia (Flora Europaea). Today, yellow starthistle can be found in most of the temperate areas around the world [82]. In North America, yellow starthistle now occurs in at least 41 of 50 U.S. states and 4 Canadian provinces. Yellow starthistle is reported to be adventitious in Hawaii [138]. Infestations of yellow starthistle in the eastern 2/3 of the U.S. are sporadic and localized, but apparently populations fail to establish and persist on a year-to-year basis, possibly because of unfavorable growth conditions [49,82]. Infestations west of the Rocky Mountains are most severe in California, Washington, Oregon and Idaho [20,38]. Infestations in California cover more area than those in all other states combined [82].

It is likely that there were multiple introductions of yellow starthistle to the U.S. [78], and that contaminated alfalfa seed (*Medicago sativa*) was the primary vehicle for these introductions [82]. Yellow starthistle seeds were found in adobe bricks from the period between 1824 and 1848 in California (Hendry 1931, as cited by [54]). The plant was first collected in Oakland, California in 1869 and was most likely introduced from Chile, while introductions from 1899 to 1927 appear to be from Turkestan, Argentina, Italy, France and Spain [32]. Introduction of yellow starthistle to other western states began in the late 1800s, and it was first reported outside of California near Bingen, Washington, around 1900 [30,133]. Yellow starthistle began spreading into grasslands in the Pacific Northwest in the 1920s. By 1985 yellow starthistle had spread to about 8 million acres (3.2 ha) in California [81]. Extensive road building, suburban development, and expansion in the ranching industry since the 1960s have contributed to the rapid and long-range dispersal of seed and the establishment of new satellite populations [45].

The following table reflects estimates of yellow starthistle acreage as reported by surveyed states or provinces in 1988 and again in 2000 (from [38]):

State/Province	1988	2000
Arizona	not reported	3,000
California	not reported	17,000,000
Colorado	10	100
Idaho	1,130,000	800,000
Kansas	not reported	0
Montana	1	1
Nevada	not reported	5,000
New Mexico	not reported	500
North Dakota	0	400
Oregon	10,000	950,000
South Dakota	0	0
Utah	100	2,200
Washington	133,805	1,000,000
Wyoming	0	0
Alberta	0	0
British Columbia	not reported	0
Total		19,761,201

Although inventories are more common and more accurate in the year 2000 than in 1988, 50% of these states reported only 50% accuracy, while 31% reported 51 to 75% accuracy, and 2 states reported 75 to 100% accuracy [38].

The following biogeographic classification systems are presented as a guide to demonstrate where yellow starthistle might be found or is likely to be invasive, based on reported occurrence and biological tolerance to factors that are likely to limit its distribution. Precise distribution information is limited, especially in the southwestern, southern, central, midwestern, and eastern states. Therefore, these lists are speculative and not exhaustive.

ECOSYSTEMS [44]:
FRES21 Ponderosa pine
FRES28 Western hardwoods
FRES29 Sagebrush
FRES33 Southwestern shrubsteppe
FRES34 Chaparral-mountain shrub
FRES35 Pinyon-juniper
FRES36 Mountain grasslands

FRES38 Plains grasslands
FRES39 Prairie
FRES40 Desert grasslands
FRES41 Wet grasslands
FRES42 Annual grasslands

STATES [66]:

AZ	CA	CO	CT	DE	FL	ID	IL
IN	IA	KS	KY	MD	MA	MI	MN
MO	MT	NE	NV	NH	NJ	NM	NY
NC	ND	OH	OK	OR	PA	RI	SC
SD	TN	TX	UT	VA	WA	WV	WI
WY	DC						

AB	MB	ON	SK

BLM PHYSIOGRAPHIC REGIONS [12]:
1 Northern Pacific Border
2 Cascade Mountains
3 Southern Pacific Border
4 Sierra Mountains
5 Columbia Plateau
6 Upper Basin and Range
7 Lower Basin and Range
8 Northern Rocky Mountains
9 Middle Rocky Mountains
10 Wyoming Basin
11 Southern Rocky Mountains
12 Colorado Plateau
13 Rocky Mountain Piedmont
14 Great Plains
15 Black Hills Uplift
16 Upper Missouri Basin and Broken Lands None

KUCHLER [69] PLANT ASSOCIATIONS:
K010 Ponderosa shrub forest
K022 Great Basin pine forest
K023 Juniper-pinyon woodland
K024 Juniper steppe woodland
K025 Alder-ash forest
K026 Oregon oakwoods
K030 California oakwoods
K033 Chaparral
K034 Montane chaparral
K035 Coastal sagebrush

K036 Mosaic of K030 and K035
K038 Great Basin sagebrush
K047 Fescue-oatgrass
K048 California steppe
K050 Fescue-wheatgrass
K051 Wheatgrass-bluegrass
K055 Sagebrush steppe

SAF COVER TYPES [42]:
220 Rocky Mountain juniper
221 Red alder
222 Black cottonwood-willow
233 Oregon white oak
235 Cottonwood-willow
236 Bur oak
237 Interior ponderosa pine
238 Western juniper
239 Pinyon-juniper
245 Pacific ponderosa pine
246 California black oak
247 Jeffrey pine
249 Canyon live oak
250 Blue oak-foothills pine
255 California coast live oak

SRM (RANGELAND) COVER TYPES [136]:
101 Bluebunch wheatgrass
102 Idaho fescue
103 Green fescue
104 Antelope bitterbrush-bluebunch wheatgrass
105 Antelope bitterbrush-Idaho fescue
107 Western juniper/big sagebrush/bluebunch wheatgrass
109 Ponderosa pine shrubland
110 Ponderosa pine-grassland
201 Blue oak woodland
202 Coast live oak woodland
203 Riparian woodland
204 North coastal shrub
205 Coastal sage shrub
206 Chamise chaparral
207 Scrub oak mixed chaparral
208 Ceanothus mixed chaparral
209 Montane shrubland
210 Bitterbrush
214 Coastal prairie
215 Valley grassland
235 Cottonwood-willow
311 Rough fescue-bluebunch wheatgrass
312 Rough fescue-Idaho fescue
314 Big sagebrush-bluebunch wheatgrass
315 Big sagebrush-Idaho fescue

316 Big sagebrush-rough fescue
317 Bitterbrush-bluebunch wheatgrass
318 Bitterbrush-Idaho fescue
319 Bitterbrush-rough fescue
322 Curlleaf mountain-mahogany-bluebunch wheatgrass
401 Basin big sagebrush
402 Mountain big sagebrush
403 Wyoming big sagebrush
404 Threetip sagebrush
405 Black sagebrush
406 Low sagebrush
407 Stiff sagebrush
408 Other sagebrush types
409 Tall forb
412 Juniper-pinyon woodland

HABITAT TYPES AND PLANT COMMUNITIES:
In California, yellow starthistle is widely distributed in the Central Valley and adjacent foothills, and is spreading into mountainous regions of the state below 7,000 feet (2134 m). It is less commonly found in desert, high mountain and moist coastal sites [35]. Yellow starthistle is found primarily on disturbed sites in the grassland steppe and oak woodlands [13,45,57]. California annual grasslands are dominated by many exotic species of European origin, both grasses and forbs, more than 70% of which originated in the Mediterranean region, including yellow starthistle [67]. Infestations in California and the Pacific Northwest range from scattered individuals to dense stands of yellow starthistle associated with annual grasses [133].

In the Pacific Northwest, yellow starthistle codominates with cheatgrass (*Bromus tectorum*) on over 625,000 acres (250,000 ha) of grassland steppe [131,132]. In southwestern Oregon, yellow starthistle grows on foothill sites [15]. In Washington, yellow starthistle is capable of establishment and at least short-term persistence in any of the major plant communities below subalpine. However, it is found primarily in the southeastern part of state on south-facing natural grassland slopes [113,119,121,145].

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Centaurea solstitialis

GENERAL BOTANICAL CHARACTERISTICS:
Yellow starthistle in an invasive winter annual, or rarely a biennial or short-lived perennial forb. Yellow starthistle populations in the U.S. exhibit variations in phenology (bolting and flowering time) and morphology (plant size and leaf shape) [82,117,128]. Sun [142] found genetic diversity within yellow starthistle populations, and little divergence between populations. The following description provides characteristics of yellow starthistle that may be relevant to fire ecology and is not meant to be used for identification. Keys for identifying yellow starthistle are available [49,55,56,65,115,121].

Yellow starthistle stems are stiff and erect, 6 to 72 inches (15-200 cm) in height. Stems are openly branched, except in some very small plants [30,32]. Yellow starthistle produces rosette leaves that lie close to the ground [133]. Lower leaves are 2 to 6 inches (5-15 cm) long, and progressively smaller up the stem. Upper leaves are 0.4 to 1.2 inches (1-3 cm) long, narrow and densely covered with cobwebby hairs later in the season.

Yellow starthistle inflorescences are borne in solitary flowerheads on stem tips, although vigorous plants may produce flowerheads in branch axils. The involucre is about 0.5 to 0.7 inches (1.2-1.8 cm) long. Phyllaries have 1 long central spine 0.4 to 1 inch (1.0-2.5 cm) long and 2 or more pairs of short lateral spines and are densely to sparsely covered with hairs. Yellow starthistle fruits are achenes of 2 types, both glabrous and about 2-3 mm long. Most of the achenes (seeds) (75-90%) have a short (2-5 mm), stiff pappus (plumed). Seeds at the periphery of the flowerhead are darker in color and have no pappus (plumeless).

Yellow starthistle has a large taproot that grows to soil depths of 3.3 feet (1 m) or more, allowing access to deep soil moisture during dry summer and fall months [30,116,130]. Hairs and waxy coating on mature yellow starthistle leaves reflect light, thus reducing the heat load and transpiration demand, while winged stems also dissipate heat. These qualities, along with deep roots, allow yellow starthistle to thrive under full sunlight in hot, dry conditions [30]. Vesicular arbuscular mycorrhizal fungi have been observed on yellow starthistle plants [50].

Once established, yellow starthistle can survive at high population densities, with estimates of 2-3 million plants per acre (5-7.5 million per hectare) reported. This dense cover reduces sunlight penetration to the soil surface, inhibiting germination and development of competing vegetation. Old yellow starthistle stalks are persistent and usually remain standing through the winter [20].

It has been suggested by several researchers that yellow starthistle might have an allelopathic effect on surrounding vegetation; however, there is no direct evidence to substantiate that claim [35,68].

RAUNKIAER [109] LIFE FORM:
Therophyte

REGENERATION PROCESSES:
Yellow starthistle is a facultative winter annual (sometimes biennial, from a tap root) that relies on abundant seed production for population persistence and spread [80]. The reproductive biology [80,143] and life history [131] of yellow starthistle have been explored.

Breeding system: Yellow starthistle is monoecious, pollinator-dependent and facultatively xenogamous [52,80,143]. Most yellow starthistle plants are self-incompatible [80].

Pollination:
European honeybees are an important pollinator of yellow starthistle and may be responsible for up to 57% of seed set [8,80]. Bumblebees are also important floral visitors, and several other insects contribute to the fertilization of yellow starthistle ovules [8,52].

Seed production:
The number of flowerheads and seeds produced by yellow starthistle plants varies with soil moisture and intensity of competition. Plants can produce 1 to 1,000 flowerheads per plant and 30 to 80 seeds per flowerhead [11,74,79]. Large plants can produce nearly 75,000 seeds, and Roche [117] calculated a potential 148,928 seeds produced by a nursery plant. The number of seeds per unit area produced by an infestation of yellow starthistle has been measured by several authors, with reports ranging from 14 to 100 million seeds per acre (35-250 million seeds per hectare) [23,33,74]. The number of seeds produced on an annual basis is dependent on the size of the infestation and the amount of spring precipitation [131,133]. Sheley and Larson [131] measured seed output in yellow starthistle at 1,940 and 470 seeds per square foot (21,600/m^2 and

5,200/m^2) under moist and dry spring conditions, respectively. The percentage of plumed seeds ranges from about 70 to over 90% [11,74,79,117]. In heavy infestations, yellow starthistle populations produce far more seeds than are necessary to reinfest the area year after year [30].

Seed dispersal:
Distribution of yellow starthistle seedlings is predominantly in and near the previous year's yellow starthistle debris, suggesting a relatively slow rate of spread [117]. Plumeless seeds usually remain in seedheads until fall and winter (between November and February [133]) and fall to the soil just below the parent plant as seedheads deteriorate [20]. The size of the pappus on plumed seeds is small relative to seed size and wind moves seeds only short distances, roughly equal to the height of the plant [1,114]. Roche [114] recorded 92% of seeds falling within 2 feet (0.6 m) of the parent plant, and 48% within 1 foot (0.3 m). A combination of gusty wind and dry conditions maximizes wind dispersal. Roche also measured maximum wind dispersal at about 16 feet (<5 m) over bare ground with wind gusts of 25 miles per hour (40 km/hr). While not an effective long-distance dispersal mechanism, wind dispersal can serve to increase the area of an infestation by persistently advancing the perimeter. Yellow starthistle seed can also be transported over short to medium distances by animals and humans. The pappus bristles are covered with stiff, microscopic barbs that readily adhere to clothing and hair [20,32]. Long-distance dispersal of yellow starthistle seed is often directly related to human activities and occurs by movement of livestock, vehicles, equipment, and contaminated hay and crop seed [32,35]. Birds such as ring-necked pheasants, California quail, house finches, and American goldfinches feed heavily on yellow starthistle seeds [114,117]. While some (e.g. ring-necked pheasants) may be responsible for long distance dispersal of yellow starthistle seed, most seeds consumed by birds are lost to the regeneration pool [114].

Seed losses have been recorded by researchers as a discrepancy between total seed production and number of seeds dispersed. In Washington, plumed seed was dispersed in August with a 30% loss between crop production and dispersal, and plumeless seed was released in December with a 65% loss [74]. Sheley and Larson [130] observed a 41% loss of seed production at the time of dispersal. Further losses are observed between dispersal and seedling establishment. Roche [114] found 290 seedlings per square foot (3,230/m^2) and 1.8 seeds per square foot (20/m^2) in May, in an area where about 2,630 seeds per square foot (29,200/m^2) were dispersed the previous fall. He speculated that the remaining seeds may have been consumed or moved by birds, rodents, insects or whirlwinds.

Seed banking: Yellow starthistle seed may remain viable in the soil for as long as 10 years [23]. In heavily infested areas, the soil seed bank of yellow starthistle approaches 13% of annual seed production and consists primarily of plumeless seeds [131,133]. However, evidence for seed banking in yellow starthistle varies. Induced dormancy, seed type, depth of burial, site fire history, and other site conditions may be responsible for observed differences in seed longevity.

On a bunchgrass site in California where yellow starthistle was present, no yellow starthistle seeds germinated from soil samples taken from 0 to 5 inches (0-13 cm) in October [83]. On a bunchgrass range site in Washington state that was dominated by cheatgrass and yellow starthistle (density of 16 to 21 adults per square foot (180-236/m^2)), the number of yellow starthistle seeds found in soil samples ranged from about 252 to 378 per square foot (2,800-4,200/m^2) [74,131]. On a California grassland site, seed density measurements in the soil under yellow starthistle in the fall varied from year to year in untreated, control plots from 309 to 911 per square foot (3,438-10,127/m^2) [33].

After-ripening may prevent premature germination of yellow starthistle in dry habitats. Many yellow starthistle seeds undergo secondary dormancy after exposure to high temperatures and low moisture within 1 month of dispersal. These seeds do not then germinate even under adequate light and moisture conditions [30]. Joley and others [64] observed some evidence of after-ripening in both buried and dry-stored seed, although results were inconsistent. Benefield and others [11] report 87.6 to 95.2% viability and 84 to 87.6% germination rates at the dispersal stage at 2 California sites. Thus, nearly all viable seed was able to germinate suggesting that yellow starthistle at these locations may not have an innate or induced dormancy mechanism or an ecologically significant after-ripening period.

Callihan and others [23] harvested plumed and plumeless yellow starthistle seeds from a site in Idaho, and buried them in a sandy loam soil under an annual grass community in southeast Washington at depths of 1, 2, and 6 inches (2.5, 5, and 15 cm). They detected no effects of burial depth on seed longevity, but did find that viability decreased over time. Average longevity of plumed and plumeless seeds was 10 and 6 years, respectively [23,96]. Joley and others [64] buried plumed and plumeless seeds at 2 inches (5 cm) for 72 months in the field in a sandy loam soil under a fallow orchard in north-east California. They found no effects of seed type on germination. In another study, plumed seeds were buried at several depths. After 13 months, germinable seeds increased with depth, with 0.5, 3.9, 63.1, and 88.1% germinability at 0.2, 0.4, 1, and 2 inch (0.5, 1, 2.5, and 5 cm) depths, respectively. The loss of germinable seeds at shallow depths is attributed primarily to germination, as indicated by split seedcoat.

One year of prescribed burning in Sonoma County, California, significantly reduced the seed bank of yellow starthistle ($p<0.05$) and 3 consecutive years of burning, with no further seed recruitment, further depleted the seed bank. Prior to burning, yellow starthistle seed density ranged from 309 to 911 seeds per square foot (3,438-10,127/m^2). Seed density declined to 240 seeds per square foot (2,673/ m^2) after 1 year of burning, 38 seeds per square foot (421/m^2) after 2 years of burning, and 5 to 11 seeds per square foot (52-127/m^2) after 3 consecutive years of prescribed burning. Corresponding decreases in seedling density the following springs were also observed [33]. Similarly, Joley and others [64] reported over 83% depletion in the seed bank 1 year after preventing seed rain by mowing or clipping mature plants, and after 3 years, only 3.9% of the original seeds remained. Benefield and others [11] sowed 1,000 seeds 0.4 inch (1 cm) deep in weed-free soil containers in California. They observed that after 1 year, germination and seed recovery accounted for 69% and 57% of the original 1,000 seeds sown, for plumed and plumeless seeds, respectively. Of the seeds recovered, over 80% were damaged or degraded by microbial or insect activity. Unrecovered seed was speculated to have been lost to bird or rodent predation. These results support the contention that, under California soil and climatic conditions and average field conditions where seeds are predominantly dispersed on the soil surface, yellow starthistle seeds are relatively short-lived. Microbial degradation and predation of yellow starthistle seeds probably contribute to the rapid depletion of the soil seed bank [11,30,64].

Two to 3 years of effective control can dramatically reduce yellow starthistle infestation and presence in the soil seed bank [33,64]. Yet the survival of even a small percentage of seeds can potentially lead to reinfestation of a site, even in the absence of off-site seed recruitment [23,33,64].

Germination:
The mean number of viable and germinable yellow starthistle seeds increases consistently with advancing phenological stage, with some germinable seed developing as early as the late flowering stage [80] and late senescence stage (see Seasonal Development) [11]. Plumeless seeds mature earlier than plumed seeds, and germination of plumed seeds is slightly greater than plumeless seeds [35]. Dimorphic seeds may be associated with the success of yellow starthistle in exploiting variable soil moisture and temperature regimes in semiarid environments [75]. The different seed types tend to have different optimums with regard to temperature and moisture in the lab [75,117]. In the field, the germination rate of plumed seed is higher in late fall and winter, and that of plumeless seed is higher in spring [11].

Over 90% of yellow starthistle seeds are germinable 1 week after seed dispersal [11]. Yellow starthistle seeds germinate at both low and high temperatures, allowing for both fall and spring germination when moisture is adequate [20]. In the field, seeds usually germinate in late fall or early winter, when sufficient soil moisture is present [79,133], though germination can continue throughout winter and into spring in northern California [63]. Germination is closely correlated with winter and spring rainfall events [11,79], with germination occurring throughout the rainy season, and emergence highest after early-season rainfall events [11]. The extended period of germination increases the difficulty of controlling yellow starthistle populations with late winter and early spring treatments, as germination subsequent to control efforts can result in continued infestations.

Joley and others [63] found that temperature, light, seed type, collection date, dormancy and storage, and interactions of these factors all affected yellow starthistle germination in the lab. Nearly 100% germination occurs when seeds are exposed to moisture, light and constant temperatures of 50, 59, or 68 degrees Fahrenheit (10, 15, or 20 °C), or alternating temperatures of 59:41 or 68:50 degrees Fahrenheit (15:5 or 20:10 °C). Sheley and others [128,134] found that under similar conditions of moisture and temperature and no light, germination occurred rapidly, with nearly all seed germinating within 96 hours. Total germination is reduced at temperatures above 86 degrees Fahrenheit (30 °C) and below 43 degrees Fahrenheit (6 °C) [122]. Although seeds can germinate in the dark, germination is greatly reduced in dark environments [63] and appears to be stimulated by white light [92].

Seedling establishment/growth:
Yellow starthistle seedlings first allocate resources to root extension and then to leaf expansion. Yellow starthistle root growth is vigorous and can extend deeper than 3.3 feet (1 m) during early seedling establishment [116].

In exposed areas, high germination can result in extremely dense seedling populations [74,145]. Near Walla Walla, Washington, yellow starthistle seedling populations reached winter (mid-January) densities approaching 2,500 plants per square foot (26,875 per m^2). Subsequent frost heaving reduced seedling populations by about 40%, and yellow starthistle density was further reduced by 75% during the juvenile phase (late may to mid-June) [131,133]. Similarly, Roche [117] observed a 58% reduction in yellow starthistle density from April to July. Adult density of yellow starthistle at a particular site can be closely associated with soil depth and, thus, late season water storage capacity. Roche and others [116] observed a significant relationship ($P \leq 0.001$) between the number of yellow starthistle plants per unit area and total soil moisture from 19 May to 29 August in southeastern Washington.

Asexual regeneration: There is no evidence for asexual regeneration in yellow starthistle.

SITE CHARACTERISTICS:
Yellow starthistle is most often found on roadsides and abandoned fields and pastures, waste places, recreational areas and disturbed grassland or woodland [32,49,55,158]. It is a problem primarily in moderately warm, exposed areas on relatively dry, fertile soils [32].

Yellow starthistle is best adapted to open grasslands with average annual precipitation between 10 and 60 inches (250-1500 mm). It is generally associated with deep, well-drained soils. Although populations can occur at elevations from sea level to as high as 8,000 feet (2,400 m), most large infestations are found below 5,000 feet (1,500 m) [30,82]. The optimum environmental conditions for yellow starthistle appear to be in northern California's Mediterranean-type climate (cool, wet winter and hot, dry summer), which enable yellow starthistle to grow during winter, bolt in spring, and escape summer drought [81,139]. Yellow starthistle is uncommon in deserts and moist coastal sites [32].

Yellow starthistle is capable of establishment and at least short-term persistence in any of the major plant communities in Washington below subalpine, but demonstrates its maximum potential in the bluebunch wheatgrass (*Pseudoroegneria spicata*)-Idaho fescue (*Festuca idahoensis*) zone of the steppe region of the Columbia Basin Province. In this community, on the southern slopes of the foothills of the Blue Mountains, it appears to reach its northern limits. Occasional small populations are found farther north, but the farther north the more they are restricted to steep south-facing slopes [121,145]. Here it is most competitive on deep silt loam soils on south slopes of the higher natural grassland types. In other areas, compensating factors for moisture or heat were found, or yellow starthistle was not competitive, producing only a few heads on a dwarfed plant [119]. Although yellow starthistle more readily invades and dominates south slopes and disturbed sites in southwestern Oregon, it is not restricted to them. In the absence of competitive perennial vegetation, yellow starthistle often forms dense stands on valley floors and invades openings in the conifer transition zone above oak woodlands [118]. In north-central Idaho, yellow starthistle infestations thrive in disturbed areas with high sunlight exposure and well-drained soils that receive 10-30 inches (254-762 mm) of precipitation per year [20].

On annual rangelands where yellow starthistle occurs with cheatgrass, population dominance oscillates between yellow starthistle and cheatgrass [130]. Yellow starthistle invades and dominates annual grasslands by using the deep soil moisture that remains after shallow-rooted annual grasses die in early summer [118]. Areas with deep soil and years with moderate to heavy spring rainfall give yellow starthistle the greatest advantage [74]. In dry spring conditions (and shallow soils), early maturing annual grasses have the advantage [130], although yellow starthistle can also survive at extremely low soil water potential (< -6.0 MPa) as compared to annual grasses (>-2.1 MPa) [35]. Growth rates of cheatgrass and yellow starthistle appear to depend primarily on plant density, soil depth, and available soil moisture [132]. Sheley and Larson [130] suggest that intraspecific competition is more important for both yellow starthistle and cheatgrass than is interspecific competition, citing evidence of resource partitioning via root depth, allowing for greater niche occupation on a site.

Yellow starthistle seedlings are more likely to dominate in deep silt loam and loam soils with few coarse fragments [74,145], but they can also establish on shallow, rocky soils [79,82]. In deep soils, yellow starthistle can reduce soil moisture reserves to depths greater than 6 feet (~2 m), and in 3 feet (~1 m) deep foothill soils it can extract soil moisture from fissures in bedrock [35,45]. A Washington study suggested a relationship between yellow starthistle cover and soil depth or total moisture-holding capacity of the soil on south facing aspects. Here, yellow starthistle may be dependent on the ability of the soil to retain sufficient moisture for the maturation of the plant during the summer drought period [116,117,145]. Studies in southeastern Washington natural grasslands indicated that the dual requirements of soil moisture for reproduction during the summer drought period, and light for winter growth may be critical limiting factors for yellow starthistle [116].

At its northern limit in Washington state (48° 45' north latitude), yellow starthistle is restricted to south-facing slopes [116]. Yellow starthistle's conspicuous absence on north aspects in this area appears to be related to heat and light [116,117]. This may explain why it has not persisted in British Columbia [115], and why it has gradually disappeared in northern areas of Romania (46° 47' north latitude) (Prodan (1930) as cited by [115,116]). A critical factor at the northern limits of yellow starthistle appears to be radiation during the winter [116]. Yellow starthistle needs sunlight at the soil surface from fall through spring to grow roots that can tap water stored deep in the soil during summer drought [118]. Yellow starthistle seedlings can survive extended frost periods, but mature plants rarely survive the winter in cold climates. Cold tolerance appears to be lost during the transition from vegetative to reproductive phases [30].

When yellow starthistle seed from 34 distinct stands in California, Idaho, Oregon and Washington was grown in a uniform nursery at Pullman, Washington, there was wide biotypic variation for the following variables: rosette area, decurrent leaf width, plant height, stature, number of branches, shape and form, growth stage on four dates, number of buds produced on 2 dates, flowering rate, date of first flower and first seed, average number of flowers, and seed production rate. None of the variables correlated with precipitation, elevation, or latitude of the population source [113].

SUCCESSIONAL STATUS:
Yellow starthistle does not survive well in shaded areas, and is less competitive in areas dominated by shrubs, trees, tall perennial forbs and grasses, or late-season annuals. Yellow starthistle infestations are nearly always restricted to disturbed sites or open grasslands dominated by annuals. In areas dominated by yellow starthistle,

the level of competition for light can be intense, resulting in a low rate of seedling survival through self-thinning [30,32]. The rosette growth form is particularly vulnerable to shading by overtopping vegetation (Regehr and Bazzaz 1976, as cited by [116]). Yellow starthistle is dependent on light on the soil surface for winter rosette and taproot development [117].

In an experiment in southeastern Washington, shade was indicated as a major stress factor for yellow starthistle in unclipped perennial grass stands. Yellow starthistle did not invade areas of undisturbed perennial grasses; and clipped bunchgrasses were more susceptible to yellow starthistle invasion than were clipped sod forming grasses. Yellow starthistle seedlings in plots shaded by grass litter and standing grass plants appeared weak and spindly with erect yellowish-green leaves compared to vigorous blue-green leaves of prostrate rosettes grown in grass-free control plots. Reduced light levels also reduced root growth and flower production. Plants grown under 6% full sunlight failed to flower; and the average number of flowers increased with increasing light [116].

Because yellow starthistle plants can germinate over an extended time period, the canopy of an infestation may be composed of yellow starthistle plants in several stages of development. In dense stands of yellow starthistle, the population consists of both large canopied, deep-rooted plants receiving full sunlight, and an understory of smaller, shallow-rooted, shaded plants. In this way yellow starthistle maximizes niche occupation on a site [30], and can halt native plant succession by not allowing germination and establishment of natives.

In some areas, control of one weed may lead to increase of another. Mosley and others [90] suggest that cheatgrass control may lead to replacement with yellow starthistle.

SEASONAL DEVELOPMENT:
Yellow starthistle's reproductive phenology is usually later than that of its associated vegetation, flowering after both native bunchgrasses and exotic annuals have become dormant [116,122,123]. Cohorts emerging between October and July require about 1,240 degree days for 50% of the plants to reach bud stage and an additional 500 and 900 degree days to anthesis and seed dispersal, respectively [123].

Although yellow starthistle germination occurs throughout the rainy season (October to June in California), emergence is highest after fall and early winter rainfall events [79]. Yellow starthistle plants are insensitive to photoperiod and lack a vernalization requirement, allowing late germinating plants to flower and set seed within 1 year, provided adequate moisture is available [122]. Yellow starthistle allocates resources first to root extension, then to leaf expansion, and finally to stem development and flower production [116,128]. A yellow starthistle seed germinating in fall will overwinter as a basal rosette, and may have a root penetrating to 2 feet by spring [116,117,130,134]. Rapid, deep root growth in yellow starthistle extends the period of resource availability into late summer, long after seasonal rainfall has ended and shallow-rooted annual grasses have senesced. By extending the period of resource availability, competition is reduced at the reproductive stage. Rosettes develop slowly in the early spring [30]. In most years, 60 to 75% of yellow starthistle rosettes die by July either from moisture stress or self-thinning [133]. Competition for moisture can also delay development [123].

Bolting typically occurs from late spring to early summer, coinciding with increased light availability at the time when neighboring annual species senesce and desiccate. Flowerheads are produced from early summer to late summer or fall [32]. Flowering continues until newly developing buds are killed by frost [122]. Benefield and others [11] identified 10 phenologically distinct seedhead developmental stages in yellow starthistle, ranging from late bud stage to seed dispersal. On average, seedheads required about 21 days to progress from the prebloom stage to petal abscission.

Stage	Description	Day (approximate)

Full spiny	Late bud; spines fully expanded	-
Prebloom	Florets appressed and barely protruding from apex of seedhead; white top	1-3
Flower initiation	Florets just protruding from bracts, straight up and down	3-4
Flower expansion	Florets opening, expanding downward; outside florets at 45° from vertical	4-5
Full bloom	All florets fully open and uniform in color, lemon yellow; outside florets at 90° from vertical	5-7
Initial senescence	Florets fully open but beginning to oxidize	7-8
Middle senescence	Florets continue oxidizing, becoming orange/brown; outside florets begin to close toward vertical	8-11
Late senescence	Florets further oxidized and nearly vertical, pale yellow/white; phyllaries green	11-19
Petal abscission	Florets completely oxidized; phyllaries browning	19-21
Seed dispersal	Florets abscise; phyllaries brown; pappus-bearing seeds disperse	-

*table adapted from [11]

No germinable seeds are present until 2% of spiny heads initiate flowering. The time from flower initiation to the development of mature viable seed is about 8 days. Seed production increases exponentially as percent flowering progresses, and by 10% flowering, an estimated 100 germinable seeds are produced per 100 flowerheads [11].

The species name of yellow starthistle, *solstitialis*, is Latin for "belonging to the summer solstice," alluding to the plant's summer flowering habit (Jaeger 1959 as cited by [87]). Flowering dates for yellow starthistle are reported by region as follows:

Area	Dates	References
Carolinas	June through August	[107]
Great Basin	July to September	[28]
Great Plains	July through September	[49]
Illinois	July through September	[88]
Montana	June through August	[39]
New England	August	[127]
Washington	late June through September	[115]

Plumed seeds are usually dispersed soon after flowers senesce and drop their petals. Plumeless seeds are usually retained in the seedhead until the spiny bracts fall off (about a month), but can be retained well into winter [23,30]. In early fall, yellow starthistle plants lose their leaves and dry to a silvery-gray skeleton with cottony-white terminal seedheads [133]. Senesced stems of yellow starthistle degrade slowly and may remain erect for a year [30]. With the arrival of fall rains, seeds on or in the soil begin to germinate, and the cycle is repeated [133]. Plants that germinate in spring and develop late in the season may not survive the winter post-bud stage [123].

FIRE ECOLOGY

SPECIES: Centaurea solstitialis

FIRE ECOLOGY OR ADAPTATIONS:

Fire adaptations:

Yellow starthistle is a winter annual that produces abundant seed crops. It can colonize a site after fire either from undamaged seed in the soil seed bank on site, or from seed brought to the site from an off-site source. Fire creates conditions that are favorable to the establishment of yellow starthistle (i.e. open canopy, reduced competition, areas of bare soil), so if yellow starthistle seeds are present and competition is scarce or weak, yellow starthistle will be favored in the postfire community.

Fire regimes:

Yellow starthistle occurs primarily in annual grasslands and oak woodlands in California and perennial grasslands in the Pacific Northwest, where historic fire regimes have been dramatically altered. Yellow starthistle did not occur in these communities at the time in which historic fire regimes were functioning, but has established since fire exclusion began. Hastings and DiTomaso [53] suggest that invasion of California grasslands by yellow starthistle may be due, in part, to fire suppression and reductions in fire frequency in these ecosystems. This is supported by results from prescribed fire programs in these areas that have resulted in large reductions of yellow starthistle cover, and increased native plant diversity (see Fire Case Studies) [33,53]. Additionally, dense infestations of yellow starthistle may change the fire regime by changing the fuel characteristics at a given site. In the Sugarloaf Ridge study, on a site with dense yellow starthistle, there was insufficient fine fuel to carry fire when yellow starthistle was still green [53]. Later in the season, dried skeletons of yellow starthistle can provide fuel for late summer wildfires [100].

The following table provides historic fire regime intervals for some communities and ecosystems in which yellow starthistle may be found:

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
California chaparral	*Adenostoma* and/or *Arctostaphylos* spp.	< 35 to < 100
sagebrush steppe	*Artemisia tridentata/Pseudoroegneria spicata*	20-70 [99]
basin big sagebrush	*A. tridentata* var. *tridentata*	12-43 [Sapsis1990]
mountain big sagebrush	*A. t.* var. *vaseyana*	15-40 [4,18,86]
Wyoming big sagebrush	*A. t.* var. *wyomingensis*	10-70 (40**) [156,164]
coastal sagebrush	*A. californica*	< 35 to < 100
desert grasslands	*Bouteloua eriopoda* and/or *Pleuraphis mutica*	5-100

plains grasslands	*Bouteloua* spp.	< 35
cheatgrass	*Bromus tectorum*	< 10
California montane chaparral	*Ceanothus* and/or *Arctostaphylos* spp.	50-100
California steppe	*Festuca-Danthonia* spp.	< 35
western juniper	*Juniperus occidentalis*	20-70
Rocky Mountain juniper	*J. scopulorum*	< 35
pinyon-juniper	*Pinus-Juniperus* spp.	< 35 [99]
Jeffrey pine	*P. jeffreyi*	5-30
Pacific ponderosa pine*	*P. ponderosa* var. *ponderosa*	1-47 [3]
interior ponderosa pine*	*P. p.* var. *scopulorum*	2-30 [3,6,77]
mountain grasslands	*Pseudoroegneria spicata*	3-40 (10**) [2,3]
California oakwoods	*Quercus* spp.	< 35
blue oak-foothills pine	*Q. douglasii-Pinus sabiana*	<35
Oregon white oak	*Q. garryana*	< 35 [3]
California black oak	*Q. kelloggii*	5-30 [7]
elm-ash-cottonwood	*Ulmus-Fraxinus-Populus* spp.	< 35 to 200 [36,157]

*fire return interval varies widely; trends in variation are noted in the species summary
**mean

POSTFIRE REGENERATION STRATEGY [140]:
Ground residual colonizer (on-site, initial community)
Initial off-site colonizer (off-site, initial community)
Secondary colonizer (on-site or off-site seed sources)

FIRE EFFECTS

SPECIES: Centaurea solstitialis

- IMMEDIATE FIRE EFFECT ON PLANT
- DISCUSSION AND QUALIFICATION OF FIRE EFFECT
- PLANT RESPONSE TO FIRE
- DISCUSSION AND QUALIFICATION OF PLANT RESPONSE
- FIRE MANAGEMENT CONSIDERATIONS

IMMEDIATE FIRE EFFECT ON PLANT:
Fire usually kills yellow starthistle plants [33], although some plants may resprout after low severity burning [85]. Fires are usually not severe enough to kill yellow starthistle seed. It has been suggested that heat from prescribed fires actually stimulates germination of yellow starthistle seed in the soil [53].

DISCUSSION AND QUALIFICATION OF FIRE EFFECT:
Complete destruction of yellow starthistle plants by fire is not necessary to kill the plants, although sufficient heat is required to scorch the foliage and stem-girdle and kill the plants [53].

PLANT RESPONSE TO FIRE:

Fire seems to stimulate germination of yellow starthistle seed in the soil seed bank, while also reducing competition in the plant community, reducing the thatch layer, exposing the soil, and recycling nutrients from the burned vegetation. Therefore, yellow starthistle plants that germinate following fire may grow larger and have more flowerheads the following season [53]. This might explain why Sheley and others [133] suggest that in most cases (although they cite no examples), burning increases plant size and seed production in yellow starthistle by releasing nutrients tied up in plant material.

DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:
Season and frequency of burning are important in determining yellow starthistle's response to fire. Three consecutive years of burning at early flowering stage (late June to early July in northern California) controlled yellow starthistle and depleted the yellow starthistle soil seed bank. Yellow starthistle plants may remain green for up to 4 days following burning, possibly allowing seed to mature if burning is conducted too late in the flowering stage [53]. Prescribed fires conducted early in the spring may not be hot enough to kill yellow starthistle and may damage desirable plants.

FIRE MANAGEMENT CONSIDERATIONS:
Fire as a control agent:
The effectiveness of fire in killing invasive plants or reducing their population growth depends on fire severity, time of burning, and prior and subsequent weather conditions [29], as well as the species present in the preburn community and represented in the soil seed bank. Sheley and others [133] state that burning is an ineffective method for controlling yellow starthistle; however, consecutive, annual prescribed fires have resulted in large reductions of yellow starthistle cover and seeds in the soil seed bank on some California and Oregon grassland sites [14,33,58,85]. Prescribed burning may also be a useful component in an integrated management approach [34,53,112,118].

DiTomaso [35] suggests that fire is an important component of most grassland ecosystems and that it can be used to control yellow starthistle as well as some of the invasive annual grasses with which yellow starthistle is often associated. Successful control requires timing the burn to the early flowering stage of yellow starthistle, and burning with sufficient heat to scorch the foliage and stem-girdle the plants. This heat may also stimulate seed germination, thereby facilitating seed bank depletion with repeated burning. The 1st year after burning, yellow starthistle plants emerge from seed stored in the soil. It is critical to remove these plants before they produce seed, as they are likely to be highly productive due to decreased competition [53]. Three consecutive years of burning in early July at Sugarloaf Ridge State Park in northern California reduced yellow starthistle cover by 90%, reduced yellow starthistle seeds in the soil seed bank by 99%, and increased total plant diversity and species richness [33] (see Fire Case Studies).

A similar prescription achieved somewhat different results when applied on a grassland site in the Lassen foothills of northern California [58]. For more information on the Lassen foothills project, see the Fire Management Network
on the The Nature Conservancy website. In this area, yellow starthistle and medusahead (*Taeniatherum caput-medusae)*
are both target species, and burns are timed in relation to the phenology of the dominant invasive species of individual burn units. The timing of burning for medusahead control (when it is cured, and just before seed shatter) tends to coincide with the early flowering stage in yellow starthistle [14,58]. Grazing is deferred for 3 months prior to burning to allow a build-up of fuels. Slow-spreading backfires are used and are intended to be severe enough to kill medusahead seed. Because medusahead seed is not long-lived, eradicating it requires as little as 1 year of burning, whereas yellow starthistle requires 3 years of burning and follow-up monitoring, since seeds can remain viable for several years. Two consecutive years of burning were effective in reducing cover of invasives without reducing overall plant diversity. However, plant diversity decreased after the 3rd year of burning, causing concern for several sensitive plant species in the area. The observed differences between this and the Sugarloaf Ridge site may be attributable to differences in soil type and climate; the Lassen site is a drier site [58].

Unlike mowed yellow starthistle plants, burned yellow starthistle plants do not usually resprout [14]. Minimal resprouting of scorched plants was observed following an early-spring burn where much of the vegetation was only lightly to moderately burned [85]. However, seeds on the soil surface are not typically damaged and may actually be stimulated to germinate following grassland fires, since the soil surface is only transiently heated to about 392 degrees Fahrenheit (200 °C) [35,53]. Because a single burn is likely to increase yellow starthistle plant size and seed production the following year, follow-up treatments (e.g. monitoring, repeated burning, hand-pulling) are critical to yellow starthistle control [35]. After several years of decreasing follow-up treatments, managers are able to maintain a 50-acre site free of yellow starthistle with 1 day's effort annually, in a Mediterranean annual grassland in southern Oregon [14].

One concern with consecutive annual burning is that there be sufficient fuels for prescribed burning to be effective [34]. This can be a problem where yellow starthistle populations are very dense and/or fuels are depleted with each successive burn. Prescribed fire will carry in starthistle of moderate density, but fire will not carry in very dense patches, since yellow starthistle is green at the optimal time of burning. To address this concern at Pinnacles National Monument in the Gabilan Mountains of the Central Coast Range in California, prescribed burning was coupled with seeding a sterile, annual wheat × wheatgrass hybrid in the fall to provide fuel for subsequent burns. The 1st year of burning resulted in a 98% reduction in yellow starthistle plants. Further results are forthcoming [85]. In areas where consecutive annual burning may be difficult or have negative impacts (e.g. areas with insufficient fuels, erosion concerns, or populations of sensitive species), prescribed burning may be more appropriate as part of an integrated management approach. For example, DiTomaso and others [34] suggest spraying with clopyralid the 1st year, which would suppress legumes and stimulate grasses; and burning the 2nd year, when fuel loads would be higher and the previously suppressed legume populations may be stimulated by fire.

The time of burning for effective control of yellow starthistle in California is after annual grasses have cured and before yellow starthistle flowers. There may be air quality issues and a high potential for fire to escape at this time of year. Information about prescribed fire projects should be made available to local residents prior to any burning. Escape problems can be minimized by involving the local fire departments and the California Department of Forestry [34]. Burning in the fall or spring to reduce risk of fire escape may not as effectively control and may actually benefit yellow starthistle [118]. However, Martin and Martin [85] burned earlier than is typically recommended, with 98% reduction of yellow starthistle. It is also possible to reduce risks by burning earlier in the season using a "brown and burn" technique, in which a nonselective herbicide such as glyphosate is applied, and the vegetation is allowed to cure before burning. The fire is contained more easily because surrounding vegetation is still green. The potential of fall burning to reduce weed competition for fall seedings is under investigation [118]. Yellow starthistle seedlings have also been controlled using winter or early spring flaming techniques that employ a gasoline and kerosene mixture to ignite the wet biomass and keep it burning long enough to blacken the plants [34,125]. This approach reduces risk of escaped fire and avoids major air quality issues, but it is somewhat non-selective and provides inconsistent control of yellow starthistle. It works well when followed by spring drought, but it can be a complete failure when followed by a wet spring, especially if competing species are suppressed [34].

Burning can also affect other control methods. Fire can have a serious impact on small animals and insects such as biocontrol agents and their larvae [34]. Burning to remove heavy annual plant debris improves herbicide efficacy by increasing contact with the target plants. Prescribed fire may also be used to prepare a seedbed for competitive perennials and seed broadcast in the ash [118]. In some cases, burning can lead to rapid invasion by other undesirable species from wind dispersed seeds and seeds in the soil seed bank [34].

Postfire colonization potential: The reduction in competition and litter, exposure of the soil surface to light, release of nutrients, and stimulation of germination in yellow starthistle seed associated with either wild or prescribed fire all provide ideal conditions for postfire colonization by yellow starthistle. Asher and others [5] cite a case in the Ishi Wilderness Area of northern California in which yellow starthistle provides an example of "severe postfire weed spread and impacts". No more information was given.

General precautions should be followed to prevent yellow starthistle establishment after fire. The USDA Forest Service's "Guide to noxious weed prevention practices" [154] provides several fire management considerations for weed prevention in general that can be applied to yellow starthistle. Wildfire managers might consider including weed prevention education and providing weed identification aids during fire training; avoiding known weed infestations when locating firelines, monitoring camps, staging areas, and helibases, to be sure they are kept weed free; taking care that equipment is weed free; incorporating cost of weed prevention and management into fire rehabilitation plans; and acquiring restoration funding. Careful postfire vigilance to identify and record the establishment of new populations is critical. About 1 month after fire, survey for signs of new or resprouting weeds. Repeated surveys will be needed, with the frequency and intensity guided by local conditions [5].

Potential weed problems must be addressed during prefire planning of prescribed burns, and following both wild and prescribed fires. When planning a prescribed burn, preinventory the project area and evaluate cover and phenology of any yellow starthistle present on or adjacent to the site and evaluate the potential for increased yellow starthistle populations in the area [5]. Avoid ignition and burning in areas at high risk for yellow starthistle establishment or spread, and/or plan for follow-up treatments in succeeding years. Avoid creating soil conditions that promote weed germination and establishment. Discuss weed status and risks in burn rehabilitation plans [154].

To prevent infestation, re-establish vegetation on bare ground as soon after fire as possible, using either natural recovery or artificial techniques as appropriate to site conditions and objectives. When reseeding after wildfires and prescribed burns, use only certified weed-free seed. Monitor the burn site and associated disturbed areas after the fire and the following spring for emergence of yellow starthistle, and treat to eradicate any emergent yellow starthistle plants. Regulate human, pack animal, and livestock entry into burned areas at risk for weed invasion until desirable site vegetation has recovered sufficiently to resist weed invasion. Additional guidelines and specific recommendations and requirements are available [5,47,154].

FIRE CASE STUDIES

SPECIES: Centaurea solstitialis

CASE NAME:
Sugarloaf Ridge State Park Prescribed Burns

REFERENCES:
DiTomaso, J. M.; Kyser, G. B.; Hastings, M. S. 1999 [33]
Hastings, M. S.; DiTomaso, J. M. 1996 [53]

FIRE CASE STUDY AUTHORSHIP:
Zouhar, Kris. 2002.

SEASON/SEVERITY CLASSIFICATION:
early summer/mixed severity

STUDY LOCATION:
Sugarloaf Ridge State Park, CA

PREFIRE VEGETATIVE COMMUNITY:
The grassland component of the park contains components of both native perennial vegetation, dominated by purple needlegrass (*Nassella pulchra*), blue wild rye (*Elymus glaucus*), and beardless wildrye (*Leymus triticoides*), and a variety of annual European grasses dominated by ripgut brome (*Bromus diandrus*), soft chess (*B. hordeaceus*), silver European hairgrass (*Aira caryophyllea*), wild oats (*Avena fatua*), and little quakinggrass (*Briza minor*). Scattered populations of the rare California endemic Sonoma ceanothus (*Ceanothus sonomensis*) are of special concern.

The vegetation in the study sites was predominantly yellow starthistle and annual grasses, with a "substantial" component of native perennial herbs and grasses.

TARGET SPECIES PHENOLOGICAL STATE:
Prescribed burns were carefully timed to prevent seed production in yellow starthistle, while allowing for seed dispersal and senescence of associated vegetation, thus stacking the seed bank in favor of desirable species and providing a dry fuel source. Burns were timed to the early flowering stage or late floral bud stage of yellow starthistle, when less than 10% of flower buds were opened (see Seasonal Development).

SITE DESCRIPTION:
Sugarloaf Ridge State Park is in the northern Coast Range of California near Sonoma. It is a dry, low-elevation woodland with large expanses of open grassland. Nearly all open grassland areas have been severely infested with yellow starthistle since 1989. Burns were conducted on 2 open grassland sites within the study area at 2 different time periods. Site A (35 acres (14 ha) of heavily infested grassland) was burned in 1993, 1994, and 1995; and Site B (175 acre (70 ha) grassland) was similarly burned in 1995, 1996, and 1997.

FIRE DESCRIPTION:
Burns were conducted annually over a 3-year period at each site. All burns were conducted in early July except for the 1997 burn, which was conducted in late June due to early development of yellow starthistle. Burns were initiated with a drip torch and a steady backing fire was sustained in most locations. In all locations, the fire carried well with an average 4-foot (1.2 m) flame length. Average maximum temperature at the soil surface, measured with temperature pellets, was about 426 degrees Fahrenheit (219 °C) in the 1st year burn area, 448 degrees Fahrenheit (231 °C) in previously burned areas, and ranged from 300 to 576 degrees Fahrenheit (149-302 °C), for all burns in all years. Burns were conducted at ambient temperatures between 70 and 81 degrees Fahrenheit (21- 27 °C), relative humidity between 35 and 52% and light winds ranging between 1.8 and 4.8 miles/hour (3-8 km/hour). Fires burned unevenly resulting in a patchwork of high to low severity areas on a scale of a few meters in size.

In all years and over most of the area, the dried vegetation carried the fire well, with the exception of a severely eroded gully, where there was insufficient grass and fine fuel to carry fire the 2nd year of burning and yellow starthistle cover approached 100%. Additionally, in 3rd year burns, both flame-length and rate of spread were reduced due to reduction of fine fuel accumulations by previous fires.

FIRE EFFECTS ON TARGET SPECIES:
Fire caused nearly complete mortality of yellow starthistle, although plants remained green and fleshy for up

to 4 days following scorching.

After a single year of burning, percent cover of yellow starthistle measured the following spring showed a significant decrease ($p<0.05$), compared to both the previous year and to the unburned control in the same year. However, the percent cover of yellow starthistle that summer was not different than percent cover in the unburned control or in the same site the prior year. This is because while stem density decreased, the individual plants were bigger and produced more seedheads per plant in the burn sites, compared to unburned control sites. Therefore, a significant ($p<0.05$) reduction in summer cover of yellow starthistle was not observed until after a 2nd year of burning. Yellow starthistle cover was further reduced after a 3rd year of burning, but differences were not significant compared to 2nd year data.

The reduction in yellow starthistle vegetative cover following 3 consecutive years of burning corresponded to a depletion of yellow starthistle seeds in the soil seed bank. After 3 consecutive annual burns, the soil seed banks at sites A and B were reduced by 99.5 and 96.3%, respectively, compared to the unburned control in the same year. Some results from this study are given below:

Site	Treatment	Year	Yellow starthistle % cover (spring)	Yellow starthistle % cover (summer)
A	2-year burn	1995	3.1	26.2
	3-year burn	1996	0.7	6.9
B	Prior to burn	1995	28.6	79.3
	1-year burn	1996	12.9	64.7
	2-year burn	1997	2.1	8.0
	3-year burn	1998	1.5	11.3
Control	Unburned	1995	30.5	80.2
		1996	29.0	73.6
		1997	25.8	52.9
		1998	29.1	76.0

Fire effects on associated plant species were also documented. After the 1st year of burning, some increases in the abundance and diversity of native plant species on burned sites were documented, while exotic species increased on unburned control plots. Spring cover of native perennial grasses, primarily purple needlegrass, initially decreased following the 1st burn on site B (possibly due to decrease in the size of the clumps rather than to clump mortality), but increased significantly after 3 consecutive years of burning. Burning did not have a significant effect on the percent cover of introduced annual grasses or total forbs; however, there was a change in the proportion of native and introduced forbs. Over all sites, native forb cover increased from 17% to 67% of total forb cover after 3 years of burning. Results also indicate an increase in species richness and diversity on burned sites compared to unburned controls. Increases in the abundance and diversity of native plant species are possibly attributable to reduced competition from yellow starthistle, increased light, and higher soil temperatures in the spring. Fires killed most of the mature Sonoma ceanothus plants, and seemed to stimulate germination of seeds, although observations were not quantified.

FIRE MANAGEMENT IMPLICATIONS:
Proper timing is critical to the successful use of prescribed burning for yellow starthistle suppression. In northern California grasslands, a burn window opens before yellow starthistle produces seed and after desirable grasses and broadleaf species have completed their reproductive cycle and cured; thus providing dry fuel for the fire. Burning at this time should lead to depletion of the yellow starthistle seed bank and to an increase in seed bank, establishment, and competitive ability of desirable species.

Timing of the burn is more important than fire intensity, since complete destruction of yellow starthistle plants by fire is not necessary, and plants may remain green for up to 4 days following burning. This could allow seed to mature if burning was conducted too late in the flowering stage. Sufficient heat is required to scorch the foliage and stem-girdle the plants. This heat may also stimulate seed germination, thereby facilitating seed bank depletion with subsequent burning.

With consecutive annual burns, there is also some concern whether sufficient fuel will be present for burning in latter years. For example, in a severely eroded gully within the burn area at Sugarloaf Ridge, there was insufficient grass and fine fuel to carry fire the 2nd year, and yellow starthistle cover approached 100%. At this site, managers broadcast sowed seeds of 2 non-invasive, non-native annual grasses in early December to provide fuels for the following year's burn.

MANAGEMENT CONSIDERATIONS

SPECIES: Centaurea solstitialis

IMPORTANCE TO LIVESTOCK AND WILDLIFE:
Cattle, sheep and goats will graze on yellow starthistle in early spring, and up to the bolting stage. These ruminants will not graze yellow starthistle plants after the spines emerge [82,133,139,148,149,150]. Yellow starthistle provides forage for ruminants in late spring and early summer when other green forage is generally unavailable [150]. Yellow starthistle is toxic to horses, causing a neurological disease called equine nigropallidal encephalomalacia, or "chewing disease" with prolonged ingestion. Poisoning is most likely when yellow starthistle is the only feed available (e.g. on poor condition range) or when yellow starthistle is a substantial contaminant of dried hay. In some cases, horses acquire a taste for yellow starthistle and seek it out even when other forage is available [98]. Other animals (e.g. mules and burros) are not susceptible to the toxic effects [24,30].

Yellow starthistle foliage may be eaten by grasshoppers, and yellow starthistle seeds are consumed by several species of birds including ring-necked pheasants, California quail, house finches, and American goldfinches [32,117].

PALATABILITY:
No information

NUTRITIONAL VALUE:
It has been suggested that the nutritional value of yellow starthistle is low, and that cattle subsisting on the plant will lose weight (Callihan and others 1982, as cited by [82]). The nutritional component of yellow starthistle leaves is highly digestible by ruminants during the growing season [22], but its nutrient value declines as the plants mature [82]. Measures of protein and acid detergent fiber (ADF) content by Thomsen and others [148] indicate that yellow starthistle has acceptable nutritional value as a component of a ruminants diet. In the rosette stage protein content ranged between 10 and 13% and acid detergent fiber (ADF) between 26 and 28%. In the bolting to early bud stage, protein content was 11 to 13% and ADF was 28 to 32%. An analysis of the nutritional status of cattle manure in the fall indicated that yellow starthistle infested pastures

contain considerably less crude protein and total digestible nutrients compared to uninfested pastures (Barry 1995, as cited by [30]).

COVER VALUE:
Gray and Greaves [48] and Olson and Gray [97] report some use of yellow starthistle for cover and nesting by Least Bell's Vireo in California.

OTHER USES:
Yellow starthistle is regarded as an important honey source plant in California and other western states [30]. Yellow starthistle is used in Turkish folk medicine for the treatment of ulcers. In a laboratory study, aqueous extracts of fresh or dried flowers of yellow starthistle given orally showed significant ($p<0.01$) antiulcerogenic activity in rats [163].

IMPACTS AND CONTROL:
Impacts:
Infestations of yellow starthistle can displace native plants, reduce native wildlife habitat and forage, decrease native plant and animal diversity, limit access to recreational areas, and reduce land value [30,120]. Dense infestations of yellow starthistle can fragment sensitive plant and animal habitat [30]. Several rare and sensitive plant species such as agate desertparsley (*Lomatium cookii*) on the Agate Desert Preserve in southwestern Oregon, and California bearpoppy (*Arctomecon californica*) on the Ash Meadow Preserve in Nevada, along with several plant species on the Garden Creek Ranch preserve in Idaho are thought to be threatened by yellow starthistle [108,111]. Large populations of yellow starthistle deplete soil moisture reserves and alter the water cycle in annual grassland and foothill woodland ecosystems in California, by using more water to a greater soil depth than would native or desirable vegetation [9,30,34,45]. Because dense infestations of yellow starthistle use deep soil moisture reserves earlier than associated natives such as blue oak (*Quercus douglasii*) or purple needlegrass (*Nasella pulchra*), native species can experience drought conditions even in years with normal rainfall [9,45]. It has been suggested that this can cause large annual economic losses in water conservation costs in California [37]. Other economic losses may occur from interference with livestock grazing and forage harvesting procedures, and lower yield and forage quality of rangelands [30]. Yellow starthistle is toxic to horses, causing a neurological disease called equine nigropallidal encephalomalacia, or "chewing disease" which is characterized by an acute inability to eat or drink, eventually causing death by starvation or dehydration [98].

Over the past 40 years, yellow starthistle has spread exponentially to infest rangelands, native grasslands, orchards, vineyards, pastures, roadsides, and waste places [35]. Estimates reached over 19 million infested acres (7.6 million ha) in the U.S. and Canada in the year 2000 [38]. In California, yellow starthistle has expanded its range from less than 1 million acres (0.4 million ha) in 1958 to roughly 10 million acres (4 million ha) in the early 1990s and is now a severe problem, infesting an estimated 17 million acres (6.8 million ha) in 2000 [108].

Control:
Control of yellow starthistle requires preventing new seed recruitment, depleting the yellow starthistle soil seed bank, and establishing desirable vegetation to thereby avoid reinfestation or replacement with other invasive species. The choice of control techniques depends on management objectives, site conditions, and available resources. Timing of treatments is a critical element for yellow starthistle control. To prevent new seed recruitment, it is most practical to gauge timing of defoliation control practices (e.g. tillage, mowing, prescribed burning) around yellow starthistle flower initiation, before approximately 2% of the total spiny heads have initiated flowering [11,30,35]. If control practices are delayed too long after flower initiation, viable seed may be produced and dispersed [11]. Except for removal of entire scattered plants, control methods are not effective if implemented when yellow starthistle is in full flower [118]. Control treatments applied in late winter or early spring may also be less effective for long-term control since yellow starthistle achenes in the seed bank may germinate and produce seed in the same season [35,122]. This may be curtailed

by planting and establishing perennial species that remove soil moisture from yellow starthistle's rooting zone prior to its maturity [73,116,122].

A brief discussion of each of the methods used for control of yellow starthistle follows. Several abstracts and articles from the proceedings of the First International Knapweed Symposium are cited in this section. These proceedings are available online (2001 Knapweed Symposium). Additionally, detailed discussions and tables displaying management options and their relative advantages, risks, timing, and fit into a strategic management plan for yellow starthistle can be seen online at the University of California Weed Research and Information Center (WRIC) [35].

Prevention:

The most cost effective method of yellow starthistle management is to prevent its establishment by maintaining a healthy community of native or otherwise desirable plants, taking care not to import yellow starthistle seed, carefully monitoring the land (especially roadsides and disturbed places) and eradicating new populations upon detection [62,135,154]. A vigorous community of desirable vegetation uses soil moisture and shades the soil surface, impeding establishment of yellow starthistle. Any activity that disturbs the soil and/or increases sunlight at the soil surface can encourage yellow starthistle [118]. Grazing management is critical to successful management of yellow starthistle on rangelands. A detailed summary of grazing management practices to deter invasion by yellow starthistle is given by DiTomaso [35] (WRIC). Managers should plan to invest strategically in routine monitoring and maintenance to locate scattered and isolated yellow starthistle plants and eliminate them [118]. Remote sensing may be useful for delineating, quantifying, and recording yellow starthistle infestations [76]. It is important to educate managers, landowners and the general public so that they can identify yellow starthistle plants, eradicate them, report their presence, and/or not distribute the seeds unknowingly [133]. The organization of cooperative weed management areas and cost-sharing programs can be effective strategies to improve weed control efforts [38,144].

Integrated management:

The goal of any management plan should be not only controlling invasive plants, but also improving the affected community, maximizing forage quality and quantity and/or preserving ecosystem integrity, and preventing reinvasion or invasion by other weed species, in a way that is complementary to the ecology and economics of the site [30,34]. Effective long-term control requires weeds be removed and replaced by more desirable and weed resistant plant communities [149]. Once the desired plant community has been determined, an integrated weed management strategy can be developed to direct succession toward that plant community by identifying key mechanisms and processes directing plant community dynamics (site availability, species availability, and species performance) and predicting plant community response to control measures [129]. This requires a long-term integrated management plan. The rapid growth, high seed viability, and seed longevity in yellow starthistle necessitate a land manager's long-term commitment to control programs [133].

Most often, a single method is not effective for controlling an invasive plant, and there are many possible combinations of methods that can achieve the desired objectives. Methods selected for removal or control of yellow starthistle on a specific site will be determined by land use objectives, desired plant community, extent and nature of the infestation(s), environmental factors (non-target vegetation, soil types, climatic conditions, important water resources), economics, and effectiveness and limitations of available control techniques [35,110]. Sometimes control techniques must be in a particular sequence to be successful. The most effective sequence for yellow starthistle control includes early season strategies in the 1st year or 2 of a management program, followed by late-season options in the later years [35] (see the (WRIC) site for more information). Consistent components of a successful program include persistence, flexibility, and most importantly, preventing new seed recruitment [34]. Also necessary for a successful integrated program is cooperation between all private and public landowners and government agencies that manage land in the area [71,91,144].

Some examples of combined approaches and considerations are presented within the following sections (e.g. [40,101,147,149,162]). Managers are encouraged to use combinations of control techniques in a manner that is appropriate to the site objectives, desired plant community, available resources, and timing of application.

Mechanical:

Mechanical control options for management of yellow starthistle typically include hand pulling, hoeing, weed whipping, tillage or mowing [30].

Manual removal (hand-pulling or digging) of yellow starthistle is most effective when small patches or scattered plants are detected before they produce a crop of seeds. Hand-pulling can be an important option in steep or uneven terrain where other mechanical tools are impossible to use [30,162], and is useful along rivers and riparian zones [133]. Hand-pulling by volunteers controlled populations of yellow starthistle in the Agate Desert Preserve in southwestern Oregon [108]. To ensure that plants do not recover, it is important to detach all aboveground stem material. A 2-inch piece of the stem can recover if leaves and buds are still attached [10].

The best time to pull yellow starthistle is after plants have bolted but before they produce viable seed. This stage is easy to recognize (see Seasonal Development) [11]. When using manual removal techniques it is important to minimize soil disturbance around removed plants since it can create an ideal site for re-establishment by new seedlings or invasion by another undesirable species [35]. In areas where yellow starthistle is growing with competing vegetation it tends to develop a more erect and slender stem and usually lacks basal leaves [116]. Under these conditions, yellow starthistle can be relatively brittle and easy to remove and will rarely recover, even when a portion of the stem is left intact [10]. Sheley and others [133] recommend transporting pulled plants in plastic bags to a location where the plants can be burned in a hot fire, to prevent spreading the seeds of flowering yellow starthistle plants. The Bradley method [43] (read about it in the Fall 1997 CALEPPC
newsletter) can be used to control yellow starthistle populations up to about 40 acres in size by physically removing plants from the outer edge of the population and moving in. The technique requires multiple visits, but helps ensure that no new seeds are produced and that soil disturbance is minimized [35]. Systematic surveys and repeated removal should be conducted every 2 to 4 weeks throughout the growing season [133].

Any tillage operation that severs the roots below the soil surface can effectively control yellow starthistle, which probably accounts for the uncommon occurrence of yellow starthistle as a cropland weed. Tillage is sometimes used for yellow starthistle control on roadsides. Early summer tillage, before viable seeds are set, and repeated tillage following rainfall/germination events [133] will rapidly deplete the yellow starthistle seed bank, but may also have the same effect on the seed bank of desirable species [35]. Tillage is not appropriate in wildlands and rangelands since it can damage important desirable species, increase erosion, alter soil structure and expose the soil for rapid reinfestations if subsequent rainfall occurs [32,35].

Mowing may be an effective control method for yellow starthistle in accessible areas under intensive management, along roadsides, in recreational areas, and where landowners do not wish to use herbicides [35,118]. Successful control with mowing depends on proper timing, the growth form of yellow starthistle [10], and the availability of desirable plants to fill the emptied niche [147,149]. The degree of control one can expect with mowing also varies with site conditions and available moisture after defoliation. It is therefore important to monitor and follow-up with whatever action may be indicated to achieve satisfactory control [147].

Mowing too early (before seedheads reach spiny stage) or too late (after seed set) will usually increase the yellow starthistle problem [10,30,147,149]. Mowing too early in the season can remove associated grass (native species are negatively impacted) cover and promotes more vigorous yellow starthistle regrowth. If done too late, mowing scatters yellow starthistle seed [118]. Thompsen and others [147,149] achieved best results at 2 sites in northern California by mowing once at the early flowering stage, and again 4 to 6 weeks later to cut regrowth during the floral bud stage. Under this regime, yellow starthistle canopy size, seed production and plant density were reduced, and plants had significantly fewer flowerheads and seedlings

($p<0.05$). Results were improved when combined with plantings of subterranean clover (*Trifolium subterraneum)*. A dense spring canopy of desirable vegetation optimizes yellow starthistle control [147]. Yellow starthistle plants with an erect, high-branching growth form are effectively controlled by a single mowing at the early flowering stage, while sprawling low-branching plants cannot be controlled even with repeated mowing [10]. Other drawbacks to mowing include a possible decrease in reproductive efforts of insect biocontrol agents, injury to native forb species [125], and reduction of fall and winter forage for wildlife and livestock [30,34,35]. However, Platt and others [102] suggest that mowing is compatible with the use of biological control agents.

Fire: See Fire Management Considerations.

Biological: Wilson and McAffrey [161], and Tu and other's Weed Control Methods Handbook [151] provide a discussion of considerations and safety issues in developing and implementing a biological control program. The objective of biological control efforts is to propagate and redistribute sufficient insect populations to hold yellow starthistle to population levels similar to their populations in Europe [153]. A detailed summary of the status of biological control of yellow starthistle in the western U.S. is given by Piper [100], and comprehensive coverage of biological control of yellow starthistle and how to establish a biocontrol program is presented by Jette and others [61].

Since 1986, 6 insects have been released for biological control of yellow starthistle:

Control agent	Mode of action	Places established or recovered [38,133]
seedhead weevil (*Bangasternus orientalis*)	attacks the early bud stages	CA,ID,OR,WA,UT
hairy weevil (*Eustenopus villosus*)	feeds on mid-stage buds and lays eggs in late-stage buds	AZ,CA,ID,OR,WA
flower weevil (*Larinus curtus*)	lays eggs in open flowers	CA,ID,OR,WA
seedhead fly (*Urophora sirunaseva*)	forms galls in seedheads	CA,OR,WA
peacock fly (*Chaetorellia australis*)	feeds in seedheads	ID,OR,WA,CA
false peacock fly (*Chaetorellia succinea*)	feeds in seedheads	CA,ID,OR,WA

Of these, *Chaetorellia succinea*
is not an approved agent and was released accidentally and is now widespread in California. Because of a risk of damage to safflower, deliberate introductions to other areas are not recommended [7]. William and others [160], however, report that this agent is also widespread in Washington and Oregon and is found on limited sites in Idaho. They also report that this agent is available for redistribution in these states. Surveys of insects investigated for biocontrol are available (e.g. [27,124]).

The 6 insects that have become established are thought to have excellent potential to diminish yellow starthistle seed production, especially *E. villosus* and *C. succinea* [100]. The impact of biocontrol insects may not be sufficient to provide complete, long-term control; however, biocontrol agents can be an important component of an integrated management approach. Where yellow starthistle occurs in dense populations and experiences high levels of intraspecific competition, however, a reduction in density through seed destruction by biocontrol agents may only release the weed from competition. The result would then be larger plants with more capitula and seeds per plant, thereby producing just as many seeds per unit area as before [152]. A more successful biocontrol program might include plant pathogens or other insects capable of severely damaging or feeding on roots, stems, or foliage [35]. Currently, a root-boring weevil (*Ceratapion basicorne*) whose larvae feed on the midrib, root crown, and stem tissues is undergoing host specificity testing and may have potential for release on yellow starthistle in the next few years [35,100].

Pathogens such as the Mediterranean rust fungus (*Puccinia jaceae*) are also being studied for control potential in yellow starthistle, though they have not been released for use [17,35,137]. The potential use of protein isolates from plant pathogens as bioherbicides is also a subject under investigation (e.g. [60,159]).

The use of grazing animals to control yellow starthistle has also been investigated and has met with some success [148,150]. Properly timed grazing by cows, sheep and goats can effectively manage yellow starthistle stands, but will not eliminate populations. Timing of grazing is critical and is more important than animal class, though there were differences in acceptance by cows, sheep and goats. Optimum control is achieved when yellow starthistle is grazed in the bolting, pre-spiny stage, followed by 1 to 3 additional grazings to remove regrowth, as long as yellow starthistle continues to bolt. The number of grazings required to suppress plants increases when spring rains replenish soil moisture [150]. Grazing in this way on California rangeland between mid-May and early July resulted in major reductions in yellow starthistle biomass, canopy size and seed production, though sufficient seed was produced or already present in soil seed bank for new plants to establish in subsequent years. This prescription must be continued for at least 3 years in a severe infestation to reduce the yellow starthistle seed bank. Grazing at this time allows annual grasses, legumes and most other resident annuals to complete their life cycle and set seed, allowing for seed bank replenishment and leaving appreciable amounts of plant residues on the ground [148,150].

Grazing alone may not provide long-term control or eradication of yellow starthistle, but can be a valuable tool in an integrated management program [30]. Both grazing alone and grazing plus herbicide applications provide some measure of success in managing yellow starthistle. While some herbicides substantially decrease yellow starthistle densities, they also eliminate all other broad-leaved plants within the sprayed strips and reduce total biomass production [148]. Additionally, a study by Enloe and others [41] indicates that other yellow starthistle management strategies may interact strongly with posttreatment grazing management. It is therefore essential to carefully prescribe grazing practices following yellow starthistle control treatments. See DiTomaso's review (WRIC) for a detailed discussion of grazing management in conjunction with yellow starthistle control.

Chemical:
Herbicides are effective in gaining initial control of a new or severe infestation of yellow starthistle, but are rarely a complete or long-term solution to weed management. If chemical control is used it must be incorporated into long-term management plans that include replacement of weeds with desirable species, careful land use management, and prevention of new infestations [19]. Improper use of herbicides can lead to several potential problems, including spray or vapor drift, water contamination, toxicity, selection for herbicide resistance in weeds and reduction in plant diversity. The WRIC website has information on herbicides used in yellow starthistle control programs including rates, timing and other considerations for their use [35]. See the Weed Control Methods Handbook for considerations on the use of herbicides in natural areas and detailed information on specific chemicals.

Several selective and nonselective herbicides are registered for control of yellow starthistle in noncrop areas, pasture, and rangeland [35,160]. Picloram is the herbicide most widely used on yellow starthistle in western states other than California, where it is not registered for use. Other herbicides used for control of yellow starthistle include clopyralid, 2,4-D, dicamba, triclopyr, chlorsulfuron, and glyphosate. Of these, clopyralid is the most effective for yellow starthistle control and the least injurious to grasses [35]. Herbicides may be applied at the seedling, rosette, or bolting stages of yellow starthistle, but higher rates are required to kill larger plants. Herbicides applied at bud and flowering stages may reduce seed formation [25,26], but may not entirely prevent the production of viable seed [118].

Of particular concern for yellow starthistle control is its resistance to picloram and some other synthetic auxin herbicides. Resistance of yellow starthistle to picloram was first observed in 1988 in a pasture in Washington that had been frequently treated with picloram during the preceding 10 years [24]. DiTomaso [35] summarizes the literature on herbicide resistance of yellow starthistle, noting that picloram resistant plants were also cross-resistant to clopyralid, dicamba and fluroxypyr, but not to triclopyr or 2,4-D, all of which are synthetic auxins and have the same mode of action as picloram (WRIC). William and others [160] and Mallory-Smith and others [84] discuss herbicide resistance and methods of prevention. Integrated approaches for the control of invasive species can greatly reduce the incidence of herbicide resistant biotypes [35]. More information on herbicide resistance is available at WeedScience.org. Repeated or continuous use of one herbicide or herbicides with the same mode of action may select not only for resistant accessions but also for other plant species demonstrating tolerance. In this way, one noxious weed may be replaced by another, equally undesirable species that is insensitive to the herbicide treatment. For example when broadleaf selective herbicides are used, noxious annual grasses such as medusahead, cheatgrass, or barbed goatgrass (*Aegilops triuncialis*) may become dominant [35].

Used alone, herbicides control yellow starthistle only temporarily, but may be a critical initial step in establishing new vegetation, and may be useful for controlling yellow starthistle among perennial grasses and protecting uninfested areas by containing yellow starthistle invasions [118]. An integrated combination of herbicide treatment and grass seeding can be effective in suppressing yellow starthistle seed production and can provide better long-term control than herbicide alone. Herbicides can also be compatible with survival of biocontrol agents. Studies combining prescribed burning and herbicide treatment have also been suggested [31,34,112].

Cultural:

Cultural control of yellow starthistle includes revegetation programs in which infested sites are seeded with either native or high forage non-native perennial grasses [35,72,73,89,93,94,95,103,104,105]. Revegetation with desirable and competitive plant species is an important part of most integrated management strategies, and can be the best long-term sustainable method of suppressing yellow starthistle invasions, establishment, or dominance while providing high forage production [30].

The degree of success or failure of any range revegetation program will depend on the selection of a grass species suited to the site (no single species or combination of species will be effective under all circumstances), the density of the established stand of grass, and the land manager's ability to maintain grass vigor after establishment [73]. Only a few species have proven to be aggressive enough to displace invasive species. In addition to being competitive, seeded species need to be adapted to local soil conditions, elevation, climate, and precipitation level of the site [35]. Monsen and McArthur [89] provide a detailed discussion of Intermountain range and watershed restoration practices, including considerations for choosing native or introduced plant materials. In any revegetation program using non-native species (or even native species from other regions), it is important to ensure that an introduced species will not itself become invasive [35]. Harrison and others [51] review several introduced species that have been used in revegetation programs in the Northwest and discuss their innate potential for invasiveness.

Although perennial grasses have been shown to be successful in competing with rangeland weeds, using a combination of species with various growth forms and ecological traits (e.g. seed mixtures with grasses and legumes) may be more effective, because a weed-resistant plant community is comprised of diverse species that occupy most of the niches, above and below ground [35,91]. Seed mixtures of grasses and forbs may be ineffective in conjunction with herbicides that kill broad-leaved plants. When using herbicides to control yellow starthistle before seeding, one can begin seeding with grasses and add forbs later. In this way, it may take several years to re-establish desirable vegetation [35].

DiTomaso [30,35] summarizes research and considerations for revegetation programs for yellow starthistle management in western states. Competitive grasses used include non-native perennial grasses such as crested wheatgrass (*A. desertorum*), intermediate wheatgrass (*Thinopyrum intermedium*), Bozoisky Russian wildrye (*Psathyrostachys juncea*), sheep fescue (*F. ovina*), tall oatgrass (*Arrhenatherum elatius*), or orchardgrass (*Dactylis glomerata*), as well as native perennial grasses including big bluegrass (*Poa ampla*) and thickspike wheatgrass (*Elymus lanceolatus* ssp. *lanceolatus*). Thill and others [146] evaluate several native and introduced species and their suitability for yellow starthistle suppression under different site conditions and objectives.

Studies in Idaho indicate that in communities dominated by bluebunch wheatgrass, intermediate wheatgrass, Idaho fescue, sheep fescue, or annual grasses, the fescue communities were least susceptible to invasion by yellow starthistle. Bluebunch wheatgrass was the most susceptible perennial grass community, and annual grass communities were even more susceptible to invasion by yellow starthistle. Yellow starthistle was susceptible to competition from perennial grass dominated communities. In addition, litter depth appeared to play a roll in suppression of yellow starthistle in both annual and perennial communities as more litter suppressed yellow starthistle germination [106]. In Oregon, Larson and McInnis [72,73] studied several grass species that have successfully controlled or reduced the rate of yellow starthistle reinvasion. Preliminary control techniques included treatment with picloram and tillage. Their results indicate that rate of yellow starthistle re-establishment can be reduced by selecting grass with competitive biomass and early growth, and that seeding without site preparation or fertilizing grasses did not control yellow starthistle reinvasion. Similarly, Borman and others [16] found that the more effective competitive species were those with early active growth and continued growth through winter. Roche and White [118] provide a detailed, step-by-step process for revegetation of yellow starthistle infestations in Oregon. In California, several species in the legume family, including non-native crimson clover (*Trifolium incarnatum*) and subterranean clover, have also been tested for their competitive effect on yellow starthistle. More research is needed to address questions of what combination of species to use in various environments, which species or combination will aggressively compete with yellow starthistle, and how to economically establish these species [35].

Researchers in California also found that integrated combinations of herbicide treatment and grass seeding can be effective in suppressing yellow starthistle seed production and provide a more effective long-term solution than applying herbicide alone [35]. When fall-dormant seedings are most practical, a late season application of glyphosate can be used to eliminate fall germination annuals such as cheatgrass and yellow starthistle that have emerged prior to application. This may substantially reduce weed competition for early season moisture the following spring [59]. Similarly, in the Northwest, established stands of wheatgrass species (Triticaceae) provide good to excellent suppression of yellow starthistle. Wheatgrasses do not have adequate seedling vigor to establish in stands of yellow starthistle, however, so yellow starthistle cover must be reduced prior to grass establishment [139].

Full recovery of desirable rangeland plants should be allowed before the area is grazed. This will help keep the plants vigorous and competitive, and minimize reinvasion by yellow starthistle [35]. Successful competition relies on limiting light to seedling yellow starthistle plants; therefore removal of too much top growth of desirable species with excessive grazing may enable yellow starthistle to recolonize a site because the shade is removed [35,118,139,146]. Studies from southeastern Washington indicate that a stand of adapted perennial grass can limit yellow starthistle if it is managed to provide shade over the soil surface from fall through spring and to deplete soil water from late spring though summer. Shallow soils do not have the potential to support enough vegetation to shade yellow starthistle, but in the absence of summer precipitation, perennials deplete soil moisture before yellow starthistle maturation and limit its competitiveness [116]. Yellow starthistle's rapid germination and root growth give it an advantage over many potential competitive, desirable species [134], making establishment of desirable species difficult because of uncertain moisture availability. Therefore management of perennial forages should focus on timing and intensity of grazing to shade yellow starthistle rosettes during the critical root development phase [116,122,148,150].

Centaurea solstitialis: References

1.
Andersen, Mark C. 1993. Diaspore morphology and seed dispersal in several wind-dispersed

Asteraceae. American Journal of Botany. 80(5): 487-492. [21433]

2.
Arno, Stephen F. 1980. Forest fire history in the Northern Rockies. Journal of Forestry. 78(8): 460-465. [11990]

3.
Arno, Stephen F. 2000. Fire in western forest ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 97-120. [36984]

4.
Arno, Stephen F.; Gruell, George E. 1983. Fire history at the forest-grassland ecotone in southwestern Montana. Journal of Range Management. 36(3): 332-336. [342]

5.
Asher, Jerry; Dewey, Steven; Olivarez, Jim; Johnson, Curt. 1998. Minimizing weed spread following wildland fires. Proceedings, Western Society of Weed Science. 51: 49. [40409]

6.
Baisan, Christopher H.; Swetnam, Thomas W. 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, U.S.A. Canadian Journal of Forest Research. 20: 1559-1569. [14986]

7.
Balciunas, Joe; Villegas, Baldo. 2001. Chaetorellia succinea--Is this unintentionally released natural enemy of yellow starthistle safe? In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 94-95. Abstract. [37872]

8.
Barthell, John F.; Thorp, Robbin W.; Wenner, Adrian M.; Randall, John M. 2000. Yellow star-thistle, gumplant, and feral honey bees on Santa Cruz Island: a case of invaders assisting invaders. In: Browne, David R.; Mitchell, Kathryn L.; Chaney, Henry W., eds. Proceedings, 5th California islands symposium; 1999 March 29 - April 1; Camarillo, CA. Santa Barbara, CA: Santa Barbara Museum of Natural History: 269-273. [40412]

9.
Benefield, Carri B.; DiTomaso, Joseph M.; Kyser, Guy B. 1998. Impacts of yellow starthistle density on the soil moisture profile and rangeland management. Proceedings, Western Society of Weed Science. 51: 66. [40408]

10.
Benefield, Carri B.; DiTomaso, Joseph M.; Kyser, Guy B.; [and others]. 1999. Success of mowing to control yellow starthistle depends on timing and plant's branching form. California Agriculture. 53(2): 17-21. [40407]

11.
Benefield, Carri B.; DiTomaso, Joseph M.; Kyser, Guy B.; Tschohl, Alison. 2001. Reproductive biology of yellow starthistle: maximizing late-season control. Weed Science. 49(1): 83-90. [40406]

12.
Bernard, Stephen R.; Brown, Kenneth F. 1977. Distribution of mammals, reptiles, and amphibians by BLM physiographic regions and A.W. Kuchler's associations for the eleven western states. Tech. Note 301. Denver, CO: U.S. Department of the Interior, Bureau of Land Management. 169 p. [434]

13.
Bernhardt, Elizabeth A.; Swiecki, Tedmund J. 1991. Minimum input techniques for valley oak restocking. In: Standiford, Richard B., technical coordinator. Proceedings of the symposium on oak woodlands and hardwood rangeland management; 1990 October 31 - November 2; Davis, CA. Gen. Tech. Rep. PSW-126. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 2-8. [17379]

14.
Borgias, Darren. 2002. [Email to Kristin Zouhar]. Yellow starthistle and fire. March 23. Medford, OR: The Nature Conservancy of Oregon. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT; RWU 4403 files. [40503]

15.
Borman, M. M.; Krueger, W. C.; Johnson, D. E. 1990. Growth patterns of perennial grasses in the annual grassland type of southwest Oregon. Agronomy Journal. 82(6): 1093-1098. [19434]

16.

Borman, M. M.; Krueger, W. C.; Johnson, D. E. 1991. Effects of established perennial grasses on yields of associated annual weeds. Journal of Range Management. 44(4): 318-322. [16119]

17.
Bruckart, W. L.; Bennett, A. R. 1989. Evaluation of Puncinia jaceae for biological control of Centaurea species: research approach and progress. In: Fay, Peter K.; Lacey, John R., eds. Proceedings of the knapweed symposium; 1989 April 4-5; Bozeman, MT. Bozeman, MT: Montana State University: 222-228. [37822]

18.
Burkhardt, Wayne J.; Tisdale, E. W. 1976. Causes of juniper invasion in southwestern Idaho. Ecology. 57: 472-484. [565]

19.
Bussan, Alvin J.; Dyer, William E. 1999. Herbicides and rangeland. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 116-132. [35716]

20.
Callihan, R. H.; Prather, T. S.; Northam, F. E. 1989. Invasion by yellow starthistle. In: Fay, Peter K.; Lacey, John R., eds. Proceedings: knapweed symposium; 1989 April 4-5; Bozeman, MT. Bozeman, MT: Montana State University: 73-76. [37798]

21.
Callihan, R. H.; Schirman, R. O.; Northam, F. E. 1990. Picloram resistance in yellow starthistle. Research Progress Report. Western Society of Weed Science. [Volume unknown]: 89-90. [24477]

22.
Callihan, Robert H.; Lass, L. W.; Hunt, C. W.; Pritchard, G. 1995. Comparative digestibility of yellow starthistle (Centaurea solstitialis L.). Western Society of Weed Science. Research Progress Report: 36. [40394]

23.
Callihan, Robert H.; Prather, Timothy S.; Northam, Francis E. 1993. Longevity of yellow starthistle (Centaurea solstitialis) achenes in soil. Weed Technology. 7: 33-35. [24469]

24.
Carlson, John E.; Willis, David B.; Michalson, Edgar L.; Callihan, Robert H. 1990. Yellow

starthistle in north-central Idaho: a survey of farmers' and ranchers' behavior and attitudes. Bulletin No. 712. Moscow, ID: University of Idaho, College of Agriculture, Agricultural Experiment Station. 11 p. [40405]

25.
Carrithers, Vanelle F.; Gaiser, Dean R.; Duncan, Celestine; Horton, Denise. 1997. Seed germination of yellow starthistle and spotted knapweed after treatment with picloram or clopyralid. Proceedings, Western Society of Weed Science. 50: 39-40. [37444]

26.
Carrithers, Vanelle F.; Gaiser, Dean R.; Duncan, Celestine; Horton, Denise. 2001. Seed germination of yellow starthistle and spotted knapweed after treatment with picloram or clopyralid. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 92-93. Abstract. [37869]

27.
Clement, Stephen L. 1990. Insect natural enemies of yellow starthistle in southern Europe and the selection of candidate biological control agents. Environmental Entomology. 19(6): 1882-1888. [24474]

28.
Cronquist, Arthur; Holmgren, Arthur H.; Holmgren, Noel H.; [and others]. 1994. Intermountain flora: Vascular plants of the Intermountain West, U.S.A. Vol. 5. Asterales. New York: The New York Botanical Garden. 496 p. [28653]

29.
D'Antonio, Carla M. 2000. Fire, plant invasions, and global changes. In: Mooney, Harold A.; Hobbs, Richard J., eds. Invasive species in a changing world. Washington, DC: Island Press: 65-93. [37679]

30.
DiTomaso, Joe. 2001. Element stewardship abstract: Centaurea solstitialis L. In: Weeds on the web: The Nature Conservancy wildland invasive species program, [Online]. Available: http://tncweeds.ucdavis.edu/esadocs/documnts/centsols.html [2001, December 19]. [40416]

31.
DiTomaso, Joseph M.; Enloe, Steven F. 2001. Integrated approaches for the management of yellow starthistle. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of

the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 63-64. Abstract. [37836]

32.
DiTomaso, Joseph M.; Gerlach, John D., Jr. 2000. Centaurea solstitialis. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 101-106. [40301]

33.
DiTomaso, Joseph M.; Kyser, Guy B.; Hastings, Marla S. 1999. Prescribed burning for control of yellow starthistle (Centaurea solstitialis) and enhanced native plant diversity. Weed Science. 47: 233-242. [40403]

34.
DiTomaso, Joseph M.; Kyser, Guy B.; Orloff, Steve B.; Enloe, Steven F. 2000. Integrated strategies offer site-specific control of yellow starthistle. California Agriculture. 54(6): 30-36. [40404]

35.
DiTomaso, Joseph. 2001. Yellow starthistle information, [Online]. Davis, CA: University of California, Weed Research and Information Center (producer). Available: htt://wric.ucdavis.edu/yst [2002, February 20]. [40415]

36.
Duchesne, Luc C.; Hawkes, Brad C. 2000. Fire in northern ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 35-51. [36982]

37. Dudley, David R. 2000. Wicked weed of the West. California Wild. 53(4): 32-35. [40401]

38.
Duncan, Celestine Lacey. 2001. Knapweed management: another decade of change. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 1-7. [37824]

39.

Duncan, Celestine; Story, Jim; Sheley, Roger. 2001. Montana knapweeds: identification, biology, and management. Circular 311 [Revised from 1998]. Bozeman, MT: Montana State University, Extension Service. 17 p. [38344]

40.
Enloe, Stephen F.; DiTomaso, Joe; Orloff, Steve; Drake, Dan. 2000. Integrated strategies for the attrition of yellow starthistle on northern California rangeland. Proceedings, California Weed Science Society. 52: 31-34. [40402]

41.
Enloe, Stephen F.; Ditomaso, Joseph M.; Drake, Daniel J.; Orloff, Steve B. 2001. The complexities of grazing management following yellow starthistle control and wheatgrass establishment. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 91. Abstract. [37868]

42.
Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 148 p. [905]

43.
Fuller, T. C.; Barbe, G. Douglas. 1985. The Bradley method of eliminating exotic plants from natural reserves. Fremontia. 13(2): 24-25. [40504]

44.
Garrison, George A.; Bjugstad, Ardell J.; Duncan, Don A.; [and others]. 1977. Vegetation and environmental features of forest and range ecosystems. Agric. Handb. 475. Washington, DC: U.S. Department of Agriculture, Forest Service. 68 p. [998]

45.
Gerlach, John; Dyer, Andrew; Rice, Kevin. 1998. Grassland and foothill woodland ecosystems of the Central Valley. Fremontia. 26(4): 39-43. [40400]

46.
Gleason, Henry A.; Cronquist, Arthur. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. 2nd ed. New York: New York Botanical Garden. 910 p. [20329]

47.

Goodwin, Kim M.; Sheley, Roger L. 2001. What to do when fires fuel weeds: A step-by-step guide for managing invasive plants after a wildfire. Rangelands. 23(6): 15-21. [40399]

48.
Gray, M. Violet; Greaves, James M. 1984. Riparian forest as habitat for the least Bell's vireo. In: Warner, Richard E.; Hendrix, Kathleen M., eds. California riparian systems: Ecology, conservation, and productive management: Proceedings of a conference; 1981 September 17-19; Davis, CA. Berkeley, CA: University of California Press: 605-611. [5862]

49.
Great Plains Flora Association. 1986. Flora of the Great Plains. Lawrence, KS: University Press of Kansas. 1392 p. [1603]

50.
Harris, P.; Clapperton, M. J. 1997. An exploratory study on the influence of vesicular-arbuscular mycorrhizal fungi on the success of weed biological control with insects. Biocontrol Science and Technology. 7(2): 193-201. [38345]

51.
Harrison, R. D.; Chatterton, N. J.; Page, R. J.; [and others]. 1996. Effects of nine introduced grasses on ecological biodiversity in the Columbia Basin. In: Rangelands in a sustainable biosphere: Proceedings, 5th international rangeland congress; 1995 July 23-28; Salt Lake City, UT. Denver, CO: Society for Range Management: 211-212. [27664]

52.
Harrod, Richy J.; Taylor, Ronald J. 1995. Reproduction and pollination biology of Centaurea and Acroptilon species, with emphasis on C. diffusa. Northwest Science. 69(2): 97-105. [28487]

53.
Hastings, Marla S.; DiTomaso, Joseph M. 1996. Fire controls yellow starthistle in California grasslands. Restoration and Management Notes. 14(2): 124-128. [40398]

54.
Heady, H. F.; Bartolome, J. W.; Pitt, M. D.; [and others]. 1992. California prairie. In: Coupland, R. T., ed. Natural grasslands: Introduction and western hemisphere. Ecosystems of the World 8A. Amsterdam, Netherlands: Elsevier Science Publishers B. V: 313-335. [23831]

55.

Hickman, James C., ed. 1993. The Jepson manual: Higher plants of California. Berkeley, CA: University of California Press. 1400 p. [21992]

56.
Hitchcock, C. Leo; Cronquist, Arthur. 1973. Flora of the Pacific Northwest. Seattle, WA: University of Washington Press. 730 p. [1168]

57.
Holzman, Barbara A.; Allen-Diaz, Barbara H. 1991. Vegetation change in blue oak woodlands in California. In: Standiford, Richard B., technical coordinator. Proceedings of the symposium on oak woodlands and hardwood rangeland management; 1990 October 31 - November 2; Davis, CA. Gen. Tech. Rep. PSW-126. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 189-197. [19059]

58.
Hujik, Peter. 2002. [Personal communication]. January 25. Los Molinos, CA: The Nature Conservancy, Dye Creek Preserve. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT; RWR 4403 files. [40501]

59.
Jacobs, James S.; Carpinelli, Michael F.; Sheley, Roger L. 1999. Revegetating noxious weed-infested rangeland. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 133-141. [35717]

60.
Jennings, James C.; Apel-Birkhold, Patricia C.; Bailey, Bryan A.; Anderson, James D. 2000. Induction of ethylene biosynthesis and necrosis in weed leaves by a Fusarium oxysporum protein. Weed Science. 48(1): 7-14. [37785]

61.
Jette, Cynthia; Connett, John; McCaffrey, Joseph P.; [and others]. 1999. Biology and biological control agents of yellow starthistle. FHTET-98-17. Morgantown, WV: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team. 93 p. [+ appendices]. [30187]

62.
Johnson, Douglas E. 1999. Surveying, mapping, and monitoring noxious weeds on rangelands. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds.

Corvallis, OR: Oregon State University Press: 19-36. [35707]

63.
Joley, D. B.; Maddox, D. M.; Mackey, B. E.; [and others]. 1997. Effect of light and temperature on germination of dimorphic achenes of Centaurea solstitialis in California. Canadian Journal of Botany. 75: 2131-2139. [28551]

64.
Joley, Donald B.; Maddox, Donald M.; Supkoff, David M.; Mayfield, Aubrey. 1992. Dynamics of yellow starthistle (Centaurea solstitialis) achenes in field and laboratory. Weed Science. 40(2): 190-194. [19446]

65.
Jones, Stanley D.; Wipff, Joseph K.; Montgomery, Paul M. 1997. Vascular plants of Texas. Austin, TX: University of Texas Press. 404 p. [28762]

66.
Kartesz, John T.; Meacham, Christopher A. 1999. Synthesis of the North American flora (Windows Version 1.0), [CD-ROM]. Available: North Carolina Botanical Garden. In cooperation with the Nature Conservancy, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service [2001, January 16]. [36715]

67.
Keeley, Jon E. 1990. The California valley grassland. In: Schoenherr, Allan A., ed. Endangered plant communities of southern California: Proceedings of the 15th annual symposium; 1989 October 28; Fullerton, CA. Special Publication No. 3. Claremont, CA: Southern California Botanists: 2-23. [21317]

68.
Kelsey, Rick G.; Bedunah, Donald J. 1989. Ecological significance of allelopathy for Centaurea species in the northwestern United States. In: Fay, Peter K.; Lacey, John R., eds. Proceedings: knapweed symposium; 1989 April 4-5; Bozeman, MT. Bozeman, MT: Montana State University: 10-32. [37791]

69.
Kuchler, A. W. 1964. United States [Potential natural vegetation of the conterminous United States]. Special Publication No. 36. New York: American Geographical Society. 1:3,168,000; colored. [3455]

70.
Lackschewitz, Klaus. 1991. Vascular plants of west-central Montana--identification guidebook. Gen. Tech. Rep. INT-227. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 648 p. [13798]

71.
Lake, Leonard; Crabtree, Carl. 2001. A landscape strategy for the management and control of yellow starthistle in the Salmon River canyon. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 88-89. Abstract. [37863]

72.
Larson, L. L.; McInnis, M. L. 1989. Impact of grass seedings on establishment and density of diffuse knapweed and yellow starthistle. Northwest Science. 63(4): 162-166. [9278]

73.
Larson, Larry L.; McInnis, Michael L. 1989. Response of yellow starthistle (Centaurea solstitialis) and grass biomass to grass, picloram, and fertilizer combinations. Weed Technology. 3: 497-500. [9345]

74.
Larson, Larry L.; Sheley, Roger L. 1994. Ecological relationships between yellow starthistle and cheatgrass. In: Monsen, Stephen B.; Kitchen, Stanley G., compilers. Proceedings--ecology and management of annual rangelands; 1992 May 18-22; Boise, ID. Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 92-94. [24260]

75.
Larson, Larry; Kiemnec, Gary. 1997. Differential germination by dimorphic achenes of yellow starthistle (Centaurea solstitialis L.) under water stress. Journal of Arid Environments. 37(1): 107-114. [40397]

76.
Lass, Lawrence W.; Carson, Hubert W.; Callihan, Robert H. 1996. Detection of yellow starthistle (Centaurea solstitialis) and common St. Johnswort (Hypericum perforatum) with multispectral digital imagery. Weed Technology. 10(3): 466-474. [40396]

77.

Laven, R. D.; Omi, P. N.; Wyant, J. G.; Pinkerton, A. S. 1980. Interpretation of fire scar data from a ponderosa pine ecosystem in the central Rocky Mountains, Colorado. In: Stokes, Marvin A.; Dieterich, John H., technical coordinators. Proceedings of the fire history workshop; 1980 October 20-24; Tucson, AZ. Gen. Tech. Rep. RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 46-49. [7183]

78.
Luster, Douglas G.; Bruckart, William L.; Pitcairn, Michael; Cristafaro, Massimo. 2001. Comparison of North American and Eurasian yellow starthistle populations using AFLP fragment pattern analysis. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 88. Abstract. [37862]

79.
Maddox, D. M. 1981. Introduction, phenology, and density of yellow starthistle in coastal, intercoastal, and central valley situations in California. Agricultural Research Results ARR-W-20. Oakland, CA: U.S. Department of Agriculture, Agricultural Research Service, Western Region. 24 p. [40411]

80.
Maddox, D. M.; Joley, D. B.; Supkoff, D. M.; Mayfield, A. 1996. Pollination biology of yellow starthistle (Centaurea solstitialis) in California. Canadian Journal of Botany. 74(2): 262-267. [26714]

81.
Maddox, Donald M.; Mayfield, Aubrey. 1985. Yellow starthistle infestations are on the increase. California Agriculture. Nov/Dec: 10-12. [40395]

82.
Maddox, Donald M.; Mayfield, Aubrey; Poritz, Noah H. 1985. Distribution of yellow starthistle (Centaurea solstitialis) and Russian knapweed (Centaurea repens). Weed Science. 33: 315-327. [23467]

83.
Major, Jack; Pyott, William T. 1966. Viable seeds in two California bunchgrass sites and their bearing on the definition of a flora. Vegetatio. 13: 253-282. [21009]

84.
Mallory-Smith, Carol; Hyslop, George R.; Thill, Donn; Morishita, Don. 1999. [Revised].

Herbicide-resistant weeds and their management. PNW 437. Moscow, ID: Pacific Northwest Extension. 6 p. [Part No. 18 in the "Weed Control Strategies" chapter of the Pacific Northwest Conservation Tillage Handbook]. [40414]

85.
Martin, Eveline L.; Martin, Ian D. 1999. Prescribed burning and competitive reseeding as tools for reducing yellow starthistle (Centaurea solstitialis) at Pinnacles National Monument. In: Kelly, Mike; Howe, Melanie; Neill, Bill, eds. Proceedings, California Exotic Pest Plant Council; 1999 October 15-17; Sacramento, CA. Volume 5. [Davis, CA]: California Exotic Pest Plant Council: 51-56. [40413]

86.
Miller, Richard F.; Rose, Jeffery A. 1995. Historic expansion of Juniperus occidentalis (western juniper) in southeastern Oregon. The Great Basin Naturalist. 55(1): 37-45. [26637]

87.
Mitich, Larry W. 1988. Thistles II: Sonchus and Centaurea. Weed Technology. 2: 380-381. [6158]

88.
Mohlenbrock, Robert H. 1986. [Revised edition]. Guide to the vascular flora of Illinois. Carbondale, IL: Southern Illinois University Press. 507 p. [17383]

89.
Monsen, Stephen B.; McArthur, E. Durant. 1995. Implications of early Intermountain range and watershed restoration practices. In: Roundy, Bruce A.; McArthur, E. Durant; Haley, Jennifer S.; Mann, David K., compilers. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19-21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 16-25. [24819]

90.
Mosely, Jeffrey C.; Bunting, Stephen C.; Manoukian, Mark E. 1999. Cheatgrass. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 175-188. [35720]

91.
Mullin, Barbara. 1992. Meeting the invasion: integrated weed management. Western Wildlands. 18(2): 33-38. [19462]

92.
Nolan, Daryl G.; Upadhyaya, Mahesh K. 1988. Primary seed dormancy in diffuse and spotted knapweed. Canadian Journal of Plant Science. 68: 775-783. [5593]

93.
Northam, F. E.; Callihan, R. H. 1988. Yellow starthistle presence in 29 month-old stands of eight grasses. Western Society of Weed Science. Research Progress Report: 60-63. [40393]

94.
Northam, F. E.; Callihan, R. H. 1990. Evaluation of soil conservation plant materials for herbicide tolerance and revegetating semi-arid land infested with yellow starthistle. Western Society of Weed Science. Research Progress Report: 75-78. [40392]

95.
Northam, F. E.; Callihan, R. H. 1990. Grass adaptation to semi-arid, yellow starthistle infested canyonland. Western Society of Weed Science. Research Progress Report: 79-82. [24471]

96.
Northam, F. E.; Prather, T. S.; Callihan, R. H. 1989. Viability and germination of buried yellow starthistle seed. Western Society of Weed Science. [Volume unknown]: 124-126. [28721]

97.
Olson, Thomas E.; Gray, M. Violet. 1989. Characteristics of least Bell's vireo nest sites along the Santa Ynez River. In: Proceedings of the California riparian systems conference: Protection, management, and restoration for the 1990's; 1988 September 22-24; Davis, CA. Gen. Tech. Rep. PSW-110. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 278-284. [14447]

98.
Panter, Kip E. 1991. Neurotoxicity of the knapweeds (Centaurea spp.) in horses. In: James, Lynn F.; Evans, John O., eds. Noxious range weeds. Westview Special Studies in Agriculture Science and Policy. Boulder, CO: Westview Press: 316-324. [23468]

99.
Paysen, Timothy E.; Ansley, R. James; Brown, James K.; [and others]. 2000. Fire in western shrubland, woodland, and grassland ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-volume 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 121-159. [36978]

100.
Piper, Gary L. 2001. The biological control of yellow starthistle in the western U.S.: four decades of progress. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 48-55. [37831]

101.
Pitcairn, M. J.; DiTomaso, J. M.; Fox, J. 1999. Integrating chemical and biological control methods for control of yellow starthistle. In: Woods, Dale M., ed. Biological control program: annual summary. Sacramento, CA: California Department of Food and Agriculture, Plant Health and Pest Prevention Services: 78-82. [40431]

102.
Platt, Stacy; McInnis, Michael L.; Larson, Larry L.; Kiemnee, Gary L. 2001. Effects of defoliation on reproduction of yellow starthistle. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 93-94. Abstract. [37871]

103.
Prather, T. S.; Callihan, R. H. 1989. Yellow starthistle trends in perennial and annual communities. Western Society of Weed Science. Research Progress Report: 130. [40389]

104.
Prather, T. S.; Callihan, R. H. 1991. Interference between yellow starthistle and pubescent wheatgrass during grass establishment. Journal of Range Management. 44(5): 443-447. [16285]

105.
Prather, T. S.; Callihan, R. H.; Thill, D. C. 1988. Revegetating yellow starthistle infested land with intermediate wheatgrass. Western Society of Weed Science. Research Progress Report: 68-69. [40391]

106.
Prather, Timothy S.; Wilson, Linda. 2001. Ability of annual and perennial grass communities to withstand invasion by yellow starthistle. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 89-90. Abstract. [37865]

107.
Radford, Albert E.; Ahles, Harry E.; Bell, C. Ritchie. 1968. Manual of the vascular flora of the Carolinas. Chapel Hill, NC: The University of North Carolina Press. 1183 p. [7606]

108.
Randall, John M. 1995. Weeds and natural areas management. In: Brenton, Robert; Sherlock, Joe, tech. coords. Proceedings: 16th annual forest vegetation management conference; 1995 January 10-12; Sacramento, CA. Redding, CA: Shasta County Opportunity Center: 23-28. [27750]

109.
Raunkiaer, C. 1934. The life forms of plants and statistical plant geography. Oxford: Clarendon Press. 632 p. [2843]

110.
Rees, N. E.; Quimby, P. C., Jr.; Mullin, B. H. 1996. Section I. Biological control of weeds. In: Rees, Norman E.; Quimby, Paul C., Jr.; Piper, Gary L.; [and others], eds. Biological control of weeds in the West. Bozeman, MT: Western Society of Weed Science. In cooperation with: U.S. Department of Agriculture, Agricultural Research Service; Montana Department of Agriculture; Montana State University: 3-24. [38273]

111.
Rice, Barry Meyers; Randall, John, compilers. 2001. Weed report: Centaurea solstitialis: yellow starthistle. In: Wildland weeds management and research: 1998-99 weed survey. Davis, CA: The Nature Conservancy, Wildland Invasive Species Program. 21 p. On file with: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. [40829]

112.
Rice, Peter; Flynn, Sarah Wilhelm. 2000. Integration of herbicides and prescribed burning for plant community restoration--Pesticide Impact Assessment Program (FS-PIAP). Unpublished study plan on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. 11 p. [38261]

113.
Roche, Ben F., Jr. 1989. Ecological notes on yellow starthistle. In: Fay, Peter K.; Lacey, John R., eds. Proceedings: knapweed symposium; 1989 April 4-5; Bozeman, MT. Bozeman, MT: Montana State University: 77-78. [37799]

114.

Roche, Ben F., Jr. 1992. Achene dispersal in yellow starthistle (Centaurea solstitialis L.). Northwest Science. 66(2): 62-65. [18414]

115.
Roche, Ben F., Jr.; Piper, Gary L.; Talbott, Cindy Jo. 1986. Knapweeds of Washington. Pullman, WA: Washington State University, Cooperative Extension, College of Agriculture and Home Economics. 41 p. [2015]

116.
Roche, Ben F., Jr.; Roche, Cindy T.; Chapman, Roger C. 1994. Impacts of grassland habitat on yellow starthistle (Centaurea solstitialis L.) invasion. Northwest Science. 68(2): 86-96. [23144]

117.
Roche, Ben Francis, Jr. 1965. Ecologic studies of yellow star-thistle (Centaurea solstitialis L.). Moscow, ID: University of Idaho. 78 p. Dissertation. [4033]

118.
Roche, C.; White, G. R. 2000. Managing yellow starthistle in southwestern Oregon. EM 8750. Corvallis, OR: Oregon State University. 8 p. [40378]

119.
Roche, Cindy Talbott. 1990. Knapweed: major populations in Washington. In: Roche, Ben F.; Roche, Cindy Talbott, eds. Range weeds revisited: Proceedings of a symposium: A 1989 Pacific Northwest range management short course; 1989 January 24-26; Spokane, WA. Pullman, WA: Washington State University, Department of Natural Resource Sciences, Cooperative Extension: 23-28. [14829]

120.
Roche, Cindy Talbott; Roche, Ben F. Jr. 1988. Distribution and amount of four knapweed (Centaurea L.) species found in eastern Washington. Northwest Science. 62(5): 242-253. [6439]

121.
Roche, Cindy Talbott; Roche, Ben F., Jr. 1991. Meadow knapweed invasion in the Pacific Northwest, U.S.A., and British Columbia, Canada. Northwest Science. 65(1): 53-61. [14144]

122.
Roche, Cindy Talbott; Thill, Donald C.; Shafii, Bahman. 1997. Reproductive phenology in yellow starthistle (Centaurea solstitialis). Weed Science. 45(6): 763-770. [40388]

123.
Roche, Cindy. 2001. Reproductive phenology in yellow starthistle. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 93. Abstract. [37870]

124.
Rosenthal, Sara S.; Davarci, Tekin; Ercis, Ahmet; [and others]. 1994. Turkish herbivores and pathogens associated with some knapweeds (Asteraceae: Centaurea and Acroptilon) that are weeds in the United States. Proceedings, Entomological Society of Washington. 96(1): 162-175. [24475]

125.
Rusmore, John T. 1995. Use of fire and cutting to control yellow starthistle (Preliminary results of a yellow starthistle control experiment). In: Lovich, Jeff; Randall, John; Kelly, Mike, eds. Proceedings, California Exotic Pest Plant Council symposium '95; 1995 October 6-8; Pacific Grove, CA. Davis, CA: Exotic Pest Plant Council: 13-19. [40410]

126.
Sapsis, David B. 1990. Ecological effects of spring and fall prescribed burning on basin big sagebrush/Idaho fescue--bluebunch wheatgrass communities. Corvallis, OR: Oregon State University. 105 p. Thesis. [16579]

127.
Seymour, Frank Conkling. 1982. The flora of New England. 2d ed. Phytologia Memoirs 5. Plainfield, NJ: Harold N. Moldenke and Alma L. Moldenke. 611 p. [7604]

128.
Sheley, R. L.; Callihan, R. H.; Huston, C. H.; Thill, D. C. 1983. Genotypic variation among yellow starthistle populations. Western Society of Weed Science. Research Progress Report: 53-54. [40387]

129.
Sheley, Roger L. 2001. Ecological principles for managing knapweed. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 62. Abstract. [37834]

130.
Sheley, Roger L.; Larson, Larry L. 1994. Comparative growth and interference between cheatgrass and yellow starthistle seedlings. Journal of Range Management. 47(6): 470-474. [40385]

131.
Sheley, Roger L.; Larson, Larry L. 1994. Observation: comparative life-history of cheatgrass and yellow starthistle. Journal of Range Management. 47(6): 450-456. [40386]

132.
Sheley, Roger L.; Larson, Larry L. 1997. Cheatgrass and yellow starthistle growth at 3 soil depths. Journal of Range Management. 50(2): 146-150. [27429]

133.
Sheley, Roger L.; Larson, Larry L.; Jacobs, James S. 1999. Yellow starthistle. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 408-416. [35760]

134.
Sheley, Roger L.; Larson, Larry L.; Johnson, Douglas E. 1993. Germination and root dynamics of range weeds and forage species. Weed Technology. 7: 234-237. [24473]

135.
Sheley, Roger; Manoukian, Mark; Marks, Gerald. 1999. Preventing noxious weed invasion. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 69-72. [35711]

136.
Shiflet, Thomas N., ed. 1994. Rangeland cover types of the United States. Denver, CO: Society for Range Management. 152 p. [23362]

137.
Shishkoff, N.; Bruckart, W. 1993. Evaluation of infection of target and nontarget hosts by isolates of the potential biocontrol agent Puccinia jaceae that infect Centaurea spp. Phytopathology. 83(9): 894-898. [38349]

138.
St. John, Harold. 1973. List and summary of the flowering plants in the Hawaiian Islands. Hong

Kong: Cathay Press Limited. 519 p. [25354]

139.
Stannard, Mark. 1993. Overview of the basic biology, distribution and vegetative suppression of four knapweed species in Washington. Plant Materials Center Technical Notes #25, [Online]. In: U.S. Department of Agriculture, Natural Resources Conservation Service, Pullman Plant Materials Center. Available: http:www.wsu.edu/pmc_nrcs/technotes/plant_materials/tntpm25.htm [2001, September 29]. [38351]

140.
Stickney, Peter F. 1989. Seral origin of species originating in northern Rocky Mountain forests. Unpublished draft on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Fire Sciences Laboratory, Missoula, MT. 10 p. [20090]

141.
Strausbaugh, P. D.; Core, Earl L. 1977. Flora of West Virginia. 2nd ed. Morgantown, WV: Seneca Books, Inc. 1079 p. [23213]

142.
Sun, Mei. 1997. Population genetic structure of yellow starthistle (Centaurea solstitialis), a colonizing weed in the western United States. Canadian Journal of Botany. 75(9): 1470-1478. [28320]

143.
Sun, Mei; Ritland, Kermit. 1998. Mating system of yellow starthistle (Centaurea solstitialis), a successful colonizer in North America. Heredity. 80(2): 225-232. [40384]

144.
Svejcar, Tony. 1999. Coordinated weed management planning. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 36-43. [35708]

145.
Talbott, C. J. 1987. Distribution and ecologic amplitude of selected Centaurea species in eastern Washington. Pullman, WA: Washington State University. Thesis. [38546]

146.
Thill, Donald C.; Roche, Cindy T.; Zamora, David L. 1999. Common crupina. In: Sheley, Roger

L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 189-201. [35723]

147.
Thomsen, Craig D.; Vayssieres, Marc P.; Williams, William A. 1997. Mowing and subclover plantings suppress yellow starthistle. California Agriculture. 51(6): 15-20. [40381]

148.
Thomsen, Craig D.; Williams, William A.; George, Melvin R.; [and others]. 1989. Managing yellow starthistle on rangeland. California Agriculture. 43(5): 4-7. [11180]

149.
Thomsen, Craig D.; Williams, William A.; Olkowski, William; Pratt, Dave W. 1996. Grazing, mowing and clover plantings control yellow starthistle. The IPM Practitioner: Monitoring the field of pest management. 18(2): 1-4. [40382]

150.
Thomsen, Craig D.; Williams, William A.; Vayssieres, Marc; [and others]. 1993. Controlled grazing on annual grassland decreases yellow starthistle. California Agriculture. 47(6): 36-40. [40383]

151.
Tu, Mandy; Hurd, Callie; Randall, John M., eds. 2001. Weed control methods handbook: tools and techniques for use in natural areas. Davis, CA: The Nature Conservancy. 194 p. [37787]

152.
Turner, Charles E. 1991. Biological control of yellow starthistle, Centaurea solstitialis L.: a progress report. In: Proceedings, 43rd California weed conference; [Date unknown]; Fremont, CA. [Place of publication unknown]: [Publisher unknown]: 78-82. On file with: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. [24476]

153.
U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 1994. Biological control of spotted and diffuse knapweeds. Program Aid Number 1529. Washington, DC: U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 15 p. [37454]

154.

U.S. Department of Agriculture, Forest Service. 2001. Guide to noxious weed prevention practices. Washington, DC: U.S. Department of Agriculture, Forest Service. 25 p. On file with: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. [37889]

155.
U.S. Department of Agriculture, National Resource Conservation Service. 2002. PLANTS database (2002), [Online]. Available: http://plants.usda.gov/. [34262]

156.
Vincent, Dwain W. 1992. The sagebrush/grasslands of the upper Rio Puerco area, New Mexico. Rangelands. 14(5): 268-271. [19698]

157.
Wade, Dale D.; Brock, Brent L.; Brose, Patrick H.; [and others]. 2000. Fire in eastern ecosystems. In: Brown, James K.; Smith, Jane Kapler, eds. Wildland fire in ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 53-96. [36983]

158.
Welsh, Stanley L.; Atwood, N. Duane; Goodrich, Sherel; Higgins, Larry C., eds. 1987. A Utah flora. The Great Basin Naturalist Memoir No. 9. Provo, UT: Brigham Young University. 894 p. [2944]

159.
Widmer, Timothy L.; Guermache, Fatiha; Vidal, Karine. 2001. Examination of a toxin produced by Alternaria spp. on yellow starthistle. In: Smith, Lincoln, ed. Proceedings, 1st international knapweed symposium of the 21st century; 2001 March 15-16; Coeur d'Alene, ID. Albany, CA: U.S. Department of Agriculture, Agricultural Research Service: 42-47. [37830]

160.
William, Ray D.; Ball, Dan; Miller, Terry L.; [and others], compilers. 2001. Pacific Northwest weed management handbook. Corvallis, OR: Oregon State University. 408 p. [38715]

161.
Wilson, Linda M.; McCaffrey, Joseph P. 1999. Biological control of noxious rangeland weeds. In: Sheley, Roger L.; Petroff, Janet K., eds. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press: 97-115. [35715]

162.
Woo, Isa; Swiadon, Laurie; Drlik, Tanya; Quarles, William. 1999. Integrated management of yellow starthistle. The IPM Practitioner: Monitoring the field of pest management. 21(7): 1-10. [40379]

163.
Yesilada, Erdem; Sezik, Ekrem; Fujita, Tetsuro; [and others]. 1993. Screening of some Turkish medicinal plants for their antiulcerogenic activities. Phytotherapy Research. 7(3): 263-265. [28718]

164.
Young, James A.; Evans, Raymond A. 1981. Demography and fire history of a western juniper stand. Journal of Range Management. 34(6): 501-505. [2659]

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