ELEMENT STEWARDSHIP ABSTRACT
for

Bromus rubens

Foxtail Brome, Red Brome

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The Nature Conservancy
Element Stewardship Abstract
For Bromus rubens

I. IDENTIFIERS

Common Name: FOXTAIL BROME Global Rank: G?

General Description:
Bromus rubens is a tufted, cool-season annual bunchgrass which characteristically reaches a height of 20 cm to 50 cm.

Diagnostic Characteristics:
The annual growth pattern, hyaline lemma, dense panicle with a purplish tinge and pubescent culm distinguish Bromus rubens from other bromes.

II. STEWARDSHIP SUMMARY

Bromus rubens is an introduced annual grass with little value. The stiff sharp florets pose a threat to livestock and native fauna. The nutritional value and land stabilizing potential are limited. Control of this species is highly feasible. The short-term viability of the seeds and the low survivability in crowded sites make eradication plausible. Shading and nutrient competition reduces the number of individual Bromus rubens plants.

III. NATURAL HISTORY

Range:
Bromus rubens was introduced into the United States from southern Europe in the mid 1800s (Burcham 1957). Most likely the introduction of this species, along with other annual exotic species with low forage value, was unintentional. By 1870 red brome was abundant in California's overgrazed rangelands (Burcham 1957). This species occurs throughout western United States from Washington to California, east to Arizona, Utah and Texas, and spotted throughout the country to Massachusetts; it is especially prevalent in the Pacific region (Hitchcock 1950, Gould 1951, Kearney and Peebles 1951).

Habitat:
Bromus rubens occurs at low to medium elevations (below 5,000 ft), in deserts and chaparral hillsides, and various places where competition from established herbaceous plants is minimal: along roadsides, waste places, rangelands and cultivated fields (Munz and Keck 1959, Beatley 1966, Crampton 1974). It is a dominant species on some rangeland that, previous to the destruction of the vegetation, were abundant in perennial native grasses (Burcham 1957, Humphrey 1977).

Bromus rubens is commonly found growing on shallow dry soil or poor textured, clayey soil (Sampson et al. 1951, Wu and Jain 1978). This cool season annual germinates in the fall and grows slowly until early spring at which time the growth rate rapidly increases, culminating with the development of the reproductive structures (Hufstader 1978). Due to the fall germination and the winter growth period, red brome grows in locales with hot, dry summers and mild, moist winters. This species is killed by winter freeze and requires between 10 cm and 25 cm of precipitation throughout its growing season (Hulbert 1955, Bartolome et al. 1980).

Bromus rubens grows on south facing slopes (Hufstader 1978) and is a common constituent in the steppe region in the Sacramento-San Joaquin valley of California (Daubenmire 1978). It is often a co- dominant or subdominant species in Coleogyne spp. communities in southern Nevada and California; Bromus tectorum, but not Bromus rubens, grows in Artemisia-Pinyon-Juniper plant communities in Nevada which occur above 5,000 feet elevation (Beatley 1966, Daubenmire 1978).

Bromus rubens often coexists with Bromus mollis or Bromus tectorum (Hulbert 1955, Wu and Jain 1979). The life-cycle and growth patterns of these species are similar, with the exception that B. tectorum is more tolerant of frost (Hulbert 1955, Bock pers. comm.). A greater amount of literature is available on B. tectorum than on B. rubens. This is due to the extensive distribution of B. tectorum in western United States, particularly in the Great Basin and Columbia Basin regions (Hulbert 1955). The distribution of Bromus rubens is far more patchy than it is for Bromus mollis; B. rubens appears to be more sensitive than B. mollis to plant competition, allelopathic substances and grazing patterns. Thus, environmental factors greatly influence the distribution of red brome, particularly in comparison to B. mollis (Wu and Jain 1979).

Ecology:
GENERAL LIFE CYCLE: Like all annual grasses, the development of Bromus rubens is comprised of six stages: germination, vegetative growth, floral bud development, maturation of flowers, fruiting, and senescence (Hufstader 1978). The prevailing environmental conditions influence the various stages of development in different ways. Germination of Bromus rubens seeds is particularly dependent on the moisture level of the soil. The ability to germinate throughout the fall, winter and spring, provide the seeds an opportunity to maximize the utilization of available moisture in order for a vigorous growth phase early in the development of the plant. In southern California, the majority of red brome seeds germinate during the end of November; the seedlings grow slowly throughout the winter with the maximum growth rate of 0.04 g/m2/day starting at the end of March and continuing through the beginning of May, at which time senescence commences (Hufstader 1978). Flowering starts in late winter and continues throughout the spring.

VEGETATIVE GROWTH: Vegetative growth commences with germination and terminates in the spring when floral development begins (Hulbert 1955). The growth rate and total standing crop appears to be relatively independent of the amount of precipitation once germination has occurred (Hufstader 1976). Plant development subsequent to germination is more dependent on the genetics of the species than it is on the environmental conditions. Growth proceeds slowly through the winter and reaches its maximum growth rate shortly before flowering (Beatley 1966, Hufstader 1978). Spring germination followed by a rapid growth period results in floral development at approximately the same time as flowering of plants that germinated in the fall (Beatley 1966). Plants that germinate in the fall are susceptible to winter freezes. Bromus rubens is not frost hardy and thus temperatures below 32 F will kill the plants (Hulbert 1955).

Crowding, especially in pure stands of red brome, decreases the survivability of individual plants (Wu and Jain 1979). A lack of reduction in number of seeds produced and a high mortality rate accompany higher density plots (Wu and Jain 1979). The section on Population Dynamics addresses these nonadaptive characteristics of Bromus rubens.

Several reasons, particularly the shallow root system and the lack of shade tolerance, account for the inability of this species to compete with established plants. In certain areas of central and southern California, red brome is an understory plant and unable to adequately compete with the larger plants for sunlight because of its delayed initial development relative to the taller species (Hufstader 1978). Competition for nutrients along with competition for light appears to be a determining factor in the size and distribution of Bromus rubens; the shallow root system limits the ability of the plant to search for nutrients deep in the soil (Humphrey 1977). Nitrogen fertilizers, but not mulch, increase the growth rate of red brome (Hulbert 1955, Bartolome et al. 1980). Hulbert (1955) speculates that the readily available nitrogen from fertilizers aids in the production of a more extensive root system; the roots are then able to compete with larger plants for water and nutrient supplies, this, in turn, allows for greater above-ground growth.

COMPETITIVE RELATIONSHIPS AND POPULATION DYNAMICS: Annual plants have an intrinsic competitive advantage: a short life-cycle, including a rapid growth phase, and the ability to produce an abundant seed source under adverse conditions (Burcham 1957, Naveh and Whittaker 1979, Cox pers. comm.). Bromus rubens follows this pattern, and grows during the cool season when adequate moisture is available. The seeds remain dormant when the environmental conditions are severe. Whereas species with low seed dormancy exhibit higher initial germination and subsequent higher mortality than species with high dormancy (Jain 1982). Bromus rubens growing in soils disturbed by testing of nuclear and other explosive devices in southern Nevada out-competes native plants which fill the same niche (Beatley 1966). It does this by requiring half as much moisture and having less exact temperature demands than the natives: 36% of native species versus 73% of Bromus rubens survive. More information on the competitive ability of red brome is available in the next section on Effects of Disturbances.

Bromus rubens is adapted to and competitive in disturbed areas, however it is not considered a problem in undisturbed sites; although it grows on open hillsides, woodlands and chaparral, most research pertains to competition with grasses and forbs in grasslands and chaparral scrub vegetation (Crampton 1974, Daubenmire 1978, Wu and Jain 1979).

Compared to other annual bromes, Bromus rubens has a patchy, limited distribution (Hulbert 1955, Wu and Jain 1979). This patchiness is due, in part, to the relatively low plasticity of red brome in response to conditions of crowding (Wu and Jain 1979). In crowding experiments, Bromus rubens displays greater self-thinning characteristics (death of individual plants), and no reduction in seed production in high plant density plots, as compared to Bromus mollis which maintains a higher plant survival rate possibly by partitioning less energy to seed production. The decrease in survival of individual plants, both in test plots and natural sites, is possibly due to the shade intolerance of Bromus rubens (Hufstader 1976). The limited intrapopulation genetic variability, resulting partially from a low outcrossing rate, may be a factor contributing to the narrow niche of Bromus rubens in California (Wu and Jain 1979).

Bromus rubens grows where sunlight and nutrients are available. The possibility of it growing in undisturbed sites exists only if bare soil and available light is present. The removal of understory herbaceous vegetation will provide a site for this winter annual to grow. Bromus rubens grows readily in open woodlands, below cottonwoods, willows and mesquite trees, where light penetrates through the canopy or through deciduous trees (Richter pers. comm., Naveh and Whittaker 1979).

High seed production aids in the survival of this species. However, the limited dispersion of the seeds results in added intra- and inter-specific competition (Wu and Jain 1979). The seeds must find a location with sufficient moisture and with limited competition from other species (Hufstader 1976). In natural populations, Bromus rubens produces an average of 76 seeds per plant, of which 18% find a safe site and result in established seedlings; however only 10% of the seedlings reach maturity (Wu and Jain 1979). With a less than 2% seed carry-over rate from the year produced to the following year, in conjunction with the low seedling establishment and low survivability quality, the invasive potential of this species is limited.

GRAZING AND FIRE: The major types of disturbances that influence the invasive potential of this species are livestock grazing and rangeland fires. The forage value of Bromus rubens is relatively low. Only during a short period of the life-cycle is it palatable to livestock; livestock, primarily sheep, graze on the plant during the winter months when it is young and green (Gould 1951, Sampson et al. 1951, Crampton 1974, Humphrey 1977). The poor quality of forage is due to the sparse foliage, the early maturity, and the stiff awns and sharp pointed florets which irritate livestock (Crampton 1974). In addition, the shallow root system is inadequate at anchoring the plant when tugged by grazers and the resulting soil-covered roots of Bromus rubens are disfavored by livestock (Humphrey 1977).

Bromus rubens has moderate erosion control abilities (Crampton 1974). Red brome is fourth to last of ten annual exotic range plants at improving range quality (Sampson et al. 1951). The poor range improvement and forage quality of Bromus rubens may explain why this species was not intentionally disseminated in western United States (Burcham 1957).

Before horses and livestock were introduced into western California the vegetation was primarily perennial species characteristic of steppe vegetation (Burcham 1957, Daubenmire 1978). By the mid 1800s the vegetation and soil had been disturbed to such an extent that plants which were adapted to disturbed environments and that were relatively unpalatable to livestock began to flourish (Burcham 1957).

Grazing and burning may increase the amount of Bromus rubens by clearing vegetation and providing adequate sites for the seeds to germinate (Hulbert 1955, Naveh and Whittaker 1979). Because seeds of annual species have a short dormancy period, they can utilize optimum conditions to germinate and complete their rapid life-cycle during the same period that disturbed perennials are slowly recovering (Naveh and Whittaker 1979).

Clipping of BROMUS spp. seedlings only slightly reduces the yield (Hulbert 1955). Mowing the plants prior to seed development results in the development of new culms; however, plants are usually killed when cut at soil level once seeds have developed (Hulbert 1955). Mowing at this stage is pointless since the seeds will be dispersed and the plant left alone would have senesced. Increasing the frequency of mowing throughout the entire growing season decreases the quantity of the yield (Hulbert 1955).

Burning (in June, October and unknown months) increases the abundance of Bromus rubens, especially in areas where the land had previously undergone disturbances (Beatley 1966, O'Leary and Westman 1988). Experiments conducted with coastal sage vegetation burned one time in June or October resulted in drastic increases in the amount of red brome in the sites where there were few vigorous native perennial plants plus a supply of Bromus rubens seeds present prior to the fire (O'Leary and Westman 1988). Possibly the effects of pollution or other stresses on summer growing perennial plants weaken the plants' ability to recover after a fire and thus the annual weeds are able to increase their percent land cover (O'Leary and Westman 1988).

Fires in sagebrush vegetation in Utah resulted in density changes of vegetation, with the burned plots having a 32% reduction in perennial grass cover and a considerable increase in the amount of annual bromes as compared to the unburned plots (Pickford 1932). A reduction in the amount of available nitrogen in burned plots in the Sonoran Desert may have a greater detrimental effect on the native perennial plants than on the introduced annuals; no deleterious effects of these fires were observed on Bromus rubens (Whysong and Heisler 1978). Over a three year period the number of red brome plants in both unburned and burned (month of burn unknown) plots in a COLEOGYNE plant community at the Nevada test site increased from 376 and 429 plants per plot, respectively, to 615 and 1,626 plants per plot, respectively (Beatley 1966).

Johnson and Smathers (1974) feel that overgrazing followed by fire suppression has resulted in an increase in the abundance of the annual brome, Bromus tectorum, in Lava Beds National Monument. Overgrazing resulted in a reduction in native perennials and an increase in the amount of annual weeds. Possibly the suppression of fires has prevented the occurrence of natural succession.

RELATIONSHIP WITH FAUNA: The eyesight of red-shouldered hawks in California is affected by Bromus rubens (McCrary and Bloom 1984). The sharp florets become lodged in the corners of the eyes, causing eye infections which lead to a reduction in vision. When the problem afflicts both eyes the hunting ability is reduced often leading to death by starvation.

Red brome is second to Tridens pulchellus in frequency of occurrence in the stomach of desert cottontails (Turkowski 1975). The animals ate the plants throughout the year, including during the flowering season. The article does not indicate whether flowers and seeds were found in the rabbits' stomachs. Rabbits ate 98% of the Bromus rubens plants which were grown in containers in the Mojave Desert (Slayback et al. 1981). Only 2% of the unprotected container plants survived.

Bromus rubens appears to be a food source of the Great Basin kangaroo rat (DIPODOMYS MICROPS). This rodent nests in areas separate from where it harvests its food (Rowland and Turner 1964).

A change in composition from a perennial shortgrass prairie to a field of introduced annual species results in changes in grasshopper distribution (Pfadt 1982). Annual grasses alone cannot support the density and diversity of grasshopper species that the native grasslands supported in this study.

Reproduction:
REPRODUCTIVE CHARACTERISTICS: The dormancy period of Bromus rubens seeds varies depending on the geographic location of the plant (Jain 1982). Genetic variability between populations may account for the direct relationship between time of maximum germination and probability of rainfall in a specific locale. Depending upon the climate of the site, the seeds, which are produced and mature in the spring, usually remain dormant throughout the hot, dry period of the summer and then germinate after the first rainfall that exceeds 1.0 cm (Hammouda and Bakr 1969). Many seeds display dormancy during the first few weeks after dissemination, but as the season progresses the degree of dormancy is significantly reduced (Jain 1982). Greater than 50% of the year's seed source germinates by the middle of September in California (Jain 1982).

Precipitation affects germination much more than it influences other stages of growth (Hufstader 1978). Rains that deliver less than 1.0 cm of water will not stimulate germination. The optimum germination conditions for Bromus rubens are temperatures between 20 C and 25 C with greater than 1.0 cm of rainfall (Hammouda and Bakr 1969). The optimum and maximum temperature for germination of Bromus tectorum seeds increases with increasing age of the seed (Hulbert 1955). About half as much rain is required (1.2 cm) to stimulate annual brome seeds to germinate than is required (2.5 cm) to stimulate native winter annuals in Nevada (Beatley 1966). This trait allows the introduced weeds to initiate development early in the season, thus giving them an advantage over the native annual species.

Moisture plays a greater role than temperature in influencing germination of red brome seeds. A germination rate of 54% occurred during three months, each with different average temperatures, provided that the moisture in the soil was not limiting (Hammouda and Bakr 1969). Seeds germinate throughout the winter and into spring following heavy rains (Beatley 1966).

Mulch in the form of plant litter may aid in germination of Bromus rubens by providing a protected site which maintains the necessary moisture and temperature conditions (Evans and Young 1970). Annual grasses, especially those with sharp pointy florets, such as red brome, require (1) an unvegetated area for the seeds to become embedded in the soil and (2) a site with optimum conditions and protection from disturbances (Pickford 1932). Nitrogen in desert soils is often limiting and mulch provides a readily available source of nitrogen to seedlings, thus aiding in the establishment of Bromus rubens (Hulbert 1955, Kay 1971). Surprisingly, mulch appears beneficial in significantly increasing the moisture availability only in areas with an annual precipitation rate of greater than 25 cm (Bartolome et al. 1980).

The tolerance of Bromus rubens to high salt and high pH conditions partially explains its success in desert soils. Delayed germination occurs when Bromus rubens seeds are grown in soil mixed with coal precipitator ash (Vollmer et al. 1982). Seeds in soil mixed without ash (pH 8.3) germinate at a 93% rate within 12 days, as compared to the delayed (24 days) low, but still significant, rates of germination (15%) occurring in soils mixed with 50% ash (pH 11.4 to pH 12.7). In addition to Bromus rubens' ability to germinate in extremely alkaline conditions is its ability to germinate (greater than 50% germination) in high osmotic potential soils treated with sodium chloride solutions of 7.5 atmospheres (Hammouda and Bakr 1969).

Increasing the depth of seed burial results in a reduced number of emerging seedlings of Bromus tectorum; 93% of seeds 4 cm deep emerge, whereas 14% of seeds 6 cm deep emerge (Hulbert 1955). Partial burial is most likely beneficial to seed germination because of the retarding effect diffuse light has on germination of B.TECTORUM seeds (Hulbert 1955).

Seed viability rapidly decreases over the first year after seeds are dispersed (Jain 1982). Approximately 100% of the seeds are viable during the initial fall after they are produced (Wu and Jain 1979). However, seed carry-over from one year to the next is less than 2% as measured by dormant seeds in the soil (Wu and Jain 1979). In contrast, seeds of Bromus tectorum stored in laboratory conditions for over 11 years demonstrate a 96% viability rate (Hulbert 1955).

Bromus rubens is a prolific seed producer: an average of 76 seeds per plant in natural populations, 142 seeds per plant in experimental mixed stand plots, or 83,600 seeds per square meter of densely spaced plants (Wu and Jain 1979). Reproductive capacity is reduced by a low seedling survival rate and by a low maturation probability (Wu and Jain 1979).

Mechanisms of seed dispersal of Bromus rubens are poorly understood. Wind carries florets of Bromus tectorum a few meters from the parent plant (Hulbert 1955). Rodent excavation may also be a means of disseminating the seeds (Hulbert 1955). Other common mechanisms of seed dispersion, such as flood sediment transport and scattering by animals, most likely aid in the dissemination of B. rubens seeds.

Most annual bromes, including Bromus rubens, are facultatively autogamous (Smith 1981). The outcrossing rate of red brome is less than 0.1% (Wu and Jain 1978). The low rate of pollen production, short filaments and lack of exserted anthers contribute to the self-pollination mechanism of red brome (Hulbert 1955, Smith 1981). Apparently, the stigma is pollinated by direct contact with the adjacent anther. This partially explains the low genetic variability within a population and, along with several other characteristics, may account for the relatively narrow niche that Bromus rubens occupies (Wu 1975, Wu and Jain 1979).

Bromus rubens is the only one of ten annual brome species tested which displays normal spring flowering when plants are kept warm during the winter and planted in the field during the spring (Hulbert 1955). All other species tested require a cold floral induction period.

The recovery potential of land invaded by this species is good, providing that competition increases form other herbaceous species. Bromus rubens is an annual plant and does not produce a dormant vegetative structure, thus recovery is based on reducing the quantity of seeds. Since less than 2% of seeds maintain their viability over a one year period, control is plausible. Crowding and shading, early in the plant's development, are detrimental to the survival of Bromus rubens (Hufstader 1976, Wu and Jain 1979).

Impacts:
As discussed previously, with low herbaceous competition Bromus rubens can be invasive and, once established, competitive with other grasses.

The awns and florets are a direct threat to livestock and native fauna (Crampton 1974). The vegetation change from perennial grasses to Bromus rubens and other annual introduced species influences the density of rabbits, grasshoppers, and kangaroo rats.

The exceptionally slow decay process of this species, up to two years in the Nevada desert, results in an abundance of dead stalks which enhance the potential for the start and spread of fires (Beatley 1966).

IV. CONDITION

V. MANAGEMENT/MONITORING

Management Requirements:
Management goals should be to reduce seed production and, if appropriate, to increase competition from native herbaceous plants. The management of annual weeds such as Bromus rubens depends on reducing the size of the seed source. Active management is advised on lands with high densities of Bromus rubens. The high seed production ability results in increased population size, particularly in disturbed land with sparse vegetation cover. However, the density of the population will be limited because of red brome's lowered survivability rate in crowded situations (Wu and Jain 1979). Annual removal of seed heads will significantly decrease the amount of Bromus rubens. Reduction in the number of weed seeds will produce available sites for native seeds to germinate and become established. Encouraging germination of native seeds will decrease the reproductive success of red brome. Bromus rubens is not competitive in vegetated sites and established native plants will out-compete the remaining seedlings. Re- establishing native plants should be relatively easy due to the lack of competitive ability of this species.

MECHANICAL CONTROL: Removal of weeds, especially annuals, can be accomplished by hoeing the plants (Lorenzi and Jeffery 1987). Plants will not reach maturity if the seedlings are uprooted and thus no seed source for the following year will be produced. This repetitive task is time consuming, especially since seeds of Bromus rubens germinate from fall through spring. An alternate approach would be to remove all the Bromus rubens plants at one time during the spring before the majority of flowering occurs. Bromus rubens plants are shallow rooted and can be easily removed from the soil by hand or with tools (Humphrey 1977, Richter pers. comm.). The fire hazard from red brome is reduced with spring raking of the dead stems at Boyce-Thompson Arboretum (Crosswhite pers. comm.). Although this method disturbs the land, the number of plants and the seed source for the following year can be decreased.

Mulching often helps in controlling annual weeds (Lorenzi and Jeffery 1987). Either a thick layer (5 cm to 13 cm) of organic mulch or a layer of black plastic will reduce the number of germinating seeds (Heathman et al. 1986, Lorenzi and Jeffery 1987). The former treatment will aid in rebuilding the often eroded topsoil whereas the latter may become a nuisance when the plastic is broken down by the sun. The effects of mulching can be variable. Due to the possibility that mulch will facilitate the growth of Bromus rubens in certain situations, the beneficial and detrimental characteristics of mulch should be tested for each individual site before attempting a large scale control using this technique. A reduction in seedling emergence of Bromus tectorum from 93% to 14% is seen when the depth of burial increases from 4 cm to 6 cm (Hulbert 1955). Since only 2% of seeds are carried over to the following year (Wu and Jain 1979), a prevention of seed development will reduce the number of mature plants.

BURNING AND GRAZING: In general, burning increases the number of annual weedy plants (Pickford 1932). However, if burning comes at a time that will prevent seed production and if native perennial plants are encouraged to grow, burning may help in changing the balance of the plant community (Johnson and Smathers 1974, O'Leary and Westman 1988). Burns conducted in late-fall may possibly damage BROMUS seedlings while encouraging the early growth of perennial grasses.

Limited controlled grazing may be beneficial, in some cases. Sheep grazing in California is used to manage weedy annual BROMUS species. Land with low density sheep grazing on the winter annual grasses results in more vigorous summer growth of the native bunchgrass STIPA PULCHRA than in adjacent areas where grazers are excluded (Reiner pers. comm.).

HERBICIDES: Due to the annual growth cycle of red brome, the most effective chemical control would be from pre-emergence herbicides. These chemicals would kill the seeds in the soil before they germinated. Impacts of herbicides on native plants may counter the benefits from killing red brome.

The soil-active herbicide atrazine is effective in reducing the amount of competition by annual brome species, as seen by an increased yield of range forage crops and sagebrush in California and Nevada (Kay 1971, Evans and Young 1977). Atrazine applied at the rate of 11.2 kg active ingredient per hectare killed Bromus rubens in the Mojave Desert, however, toxic effects were evident in the native vegetation for more than eight years (Hunter et al. 1978).

Management Programs:
There are presently no active management programs involved in controlling Bromus rubens. However, management programs on red brome are being discussed and active management programs on other annual winter bromes exist.

Management plans for Bromus rubens are being discussed at Hassayampa River Preserve. Contact: Val Little, Preserve Manager, Hassayampa River Preserve, The Nature Conservancy, Box 1162, Wickenburg, AZ, 85358. (602) 684-2772.

The following people are involved in managing other cool season annual bromes: Oren Pollack, Stewardship Ecologist, California Regional Office, The Nature Conservancy, 785 Market St, San Francisco, CA, 94103. (415) 777-0487. Cathy Macdonald, Land Steward, Oregon Field Office, The Nature Conservancy, 1205 NW 25th Ave., Portland, OR, 97210. (503) 228- 9561.

Monitoring Requirements:
Bromus rubens should be monitored to determine if the number of plants are increasing or decreasing; in particular, monitoring the number of seeds allows for prediction of the invasive potential for the following year. Yearly monitoring of the following parameters will be helpful in assessing various control techniques: aerial extent of brome plants, percent seed and percent cover of competing herbaceous plants.

The area covered by Bromus rubens can be determined using transects or winter aerial photographs (color or CIR). The increase or decrease in the extent of land covered by the weed should be determined yearly. Tagging the outer boundry of the invaded area will allow for rapid visual determination of the effectiveness of the control technique.

Visual inspection of the number and size of inflorescences is needed to determine the success in reducing the seed source. Complete elimination of the inflorescences is necessary for eradiction of the species.

Visual estimation of the extent and density of competing native herbaceous plants will allow for the prediction of a natural change in plant compostion. Thus, only limited human intervention may be necessary.

Monitoring Programs:
Bromus rubens is being monitored at the following preserve. Contact:
Val Little, Preserve Manager, Hassayampa River Preserve, The Nature Conservancy, Wickenburg, AZ 85358; (602) 684-2772.

Bromus tectorum, another cool season annual brome, is being monitored at Lawrence Memorial Grassland Preserve by censusing the percent weed coverage. Contact: Cathy Macdonald, Land Steward, The Nature Conservancy, Oregon Field Office, 1205 NW 25th Ave., Portland, OR 97210; (503) 228-9561.

VI. RESEARCH

Research Needs (General):
The ecology and genetics of Bromus rubens are well studied. This species has been used to examine the competitive ability, genetic variability and environmental plasticity between congeners. The range improvement quality and the effects of disturbances on plant growth have also been investigated. However, information on the control of this species is limited. ^More information is needed on the effects of fire, shading and clipping on Bromus rubens. The frequency and season conducted in and the developmental stage of the weed will influence the results of the control technique. ^Would the seeds be killed by a burn during the development of the inflorescence? Would buried seeds be protected from the fire? Could young seedlings survive a fire? ^How does the shade provided by the leaves of a deciduous tree effect the competitiveness of warm-season herbaceous plants in relationship to the unshaded cool-season growth of red brome? What is the difference in the competition and ecology of red brome in various habitats: grasslands with cool season competitors, open land without cool season competitors and closed woodlands with moist, mulched winter soil? What native, fast growing plants could be planted to shade and compete for nutrients with red brome? ^What types of disturbances increase red bromes ability to compete? Is the actual disturbance of the soil or the lack of competing plants more important to the initial development of red brome? ^Since germination is more dependent on moisture than on temperature, could watering in mid-summer force the seeds to germinate, resulting in death of the seedlings due to the high temperatures? ^The

temperature, humidity, soil conditions and vegetation at each site will influence the effectiveness of the manipulation and therefore the optimum control technique is expected to differ at various locations.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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