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Weed and Brush Control for Range Improvement

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Weeds and brush cause losses on rangelands by reducing forage production, increasing the cost of handling livestock, and increasing death losses of livestock due to poisoning and physical injury from spines and thorns. In addition, weeds and brush reduce water yields of watersheds, reduce accessibility of wild lands for recreationists and hunters, reduce the numbers and kinds of wildlife, and cause discomfort and stress to people through allergies and skin rash. Losses from reduced potential production caused by weeds and brush on western rangelands are estimated to total approximately $250,000,000 annually (USDA, 1965).

The weeds and brush occurring on western rangelands are as diverse as the soil types and environments of that area. They are a problem on pastures near sea level, at elevations well above 3,000 m, on very arid areas where rainfall is less than 25 cm and where rainfall is well over 125 cm annually. Although diversity is great, weeds and brush compete for light, fertilizer, and water on rangelands just as they do on cultivated lands. In many cases, competition is so severe that no range improvement can be made until this competition is removed. This discussion will illustrate this competition, the losses caused by weeds and brush, and methods that can be used to control unwanted vegetation.

I. HERBACEOUS WEEDS

Herbaceous weeds occur on all rangelands. Relatively few are present on good ranges and dense stands frequently occur on poor ranges. Likewise, the density of herbaceous weeds will vary from season to season and from site to site due to climatic, edaphic, and

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other environmental factors as well as management systems imposed upon the land. Many of the nonpoisonous plants that are recognized as weeds and are considered to be of serious economic or ecologic importance have been introduced. About half of the perennial plants are poisonous and will be discussed in a separate section. Nonpoisonous weeds cause losses that are not always spectacular but that are significant, due to the ubiquity and large numbers of such plants.

A. Downy Brome

Downy brome (*Bromus tectorum* L.) is an introduced annual grass that occurs throughout the United States. It is palatable and nutritious and supports many livestock units on western ranges each year. Downy brome forage yields fluctuate from year to year, however, and its season of use is short. Perennial forage plants give more reliable forage and yields are usually higher than from downy brome. It is an additional problem because as it matures, consumption of the grass by livestock declines and the dead plants provide fuel for range fires. A prerequisite to establishment of perennial forage plants on infested ranges is the control of downy brome and other associated weeds.

Two methods have been developed for controlling downy brome and revegetating infested ranges. Evans, Eckert, and Kay (1967) found that spraying with 0.56 kg/ha 1,1′-4,4′-bipyridinium salt (paraquat) and a surfactant followed by immediate seeding in furrows with intermediate wheatgrass (*Agropyron intermedium* [Host] Beauv.) controlled the downy brome and resulted in the establishment of high-yielding stands of intermediate wheatgrass. The spraying and seeding should be performed at a date after all downy brome has emerged and before soil moisture is depleted. This date is always a compromise but usually occurs between the end of February and the beginning of April. Evans et al. (1967) found that the addition of a low volatile ester of (2,4-dichlorophenoxy) acetic acid (2,4-D) to paraquat was necessary to control broadleaf weeds associated with downy brome. Control of broadleaf weeds as well as the weedy grasses is essential for establishment of perennial grasses on arid rangelands.

The second method of establishing perennial grasses in downy brome-infested areas is the use of a fallow technique (Eckert and Evans, 1967), in which soil active herbicides create weed-free conditions for at least 1 year. After the year of fallow, perennial grasses are seeded into seedbeds where moisture and plant nutrients have been conserved and the competition from weed seedlings is reduced. The application of 1.12 kg/ha of 2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine (atrazine) is the most promising herbicidal treatment. A fallow created by disking is also effective.

When either method was used, seeding with intermediate wheatgrass resulted in more seedlings and higher forage yields than seeding with pubescent wheatgrass [*A. trichophorum* (Link) Richt.] or standard crested wheatgrass [*A. desertorum* (Fisch.) Schult.]. Control of the annual weeds and seeding with a deep furrow drill are both essential for the establishment of perennial forage grasses.

B. Medusahead

Medusahead [*Taeniatherum asperum* (Sim.) Nevski.] is an introduced winter annual grass found on millions of hectares in California, Oregon, Washington, Idaho, and Nevada. Unlike downy brome, medusahead is not grazed by livestock except for a very short time in the spring. Invasion of rangelands in California has reduced grazing capacity as much as 75% (Major, McKell, and Berry, 1960). Torell, Erickson, and Haas (1961) estimated that this loss of forage on 284,000 ha in Idaho represented an annual gross loss of $3.5 million. Dead medusahead plants tend to form deep litter, which creates a serious fire hazard and inhibits establishment of desirable forage plants.

Medusahead is not satisfactorily controlled in the intermountain area by paraquat (Torell and Erickson, 1967; Young, Evans, and Kay, 1971), but in California, paraquat has given good control of medusahead and permitted the establishment of clovers (*Trifolium* sp.) and harding grass [*Phalaris tuberosa* var. *stenoptera* (Hack) Hitchc.] (Kay, 1964). Young et al. (1971) investigated this difference in susceptibility of medusahead to paraquat by growing selections of medusahead from 23 sources at Davis, Calif. and Reno, Nev. All selections were susceptible to paraquat at Davis but resistant at Reno. Since paraquat does not control medusahead in the intermountain area, reseeding immediately after treatment with an herbicide is not possible as with downy brome. Dalapon has proven to be the best chemical for medusahead control in the intermountain area (Young, Evans, and Eckert, 1969). Dalapon has sufficient residual phytotoxicity in the soil to cause a delay in reseeding for several months after treatment. Fallowing with a disk-harrow followed by seeding with intermediate wheatgrass is the most successful method of establishing perennial forage grasses on medusahead-infested ranges (Young et al., 1969). While the acreage of infested ranges suited to tillage—compared to the total acreage infested—is small, it is the most productive. Control of medusahead is dependent upon suppression by vigorous stands of perennial forage plants.

C. Dalmatian Toadflax

Dalmatian toadflax [*Linaria dalmatica* (L.) Mill.] has been grown as an ornamental and prized for its beautiful yellow flowers for many centuries in Europe (Talbert, 1965) but is a relatively recent introduction into the western United States. Scattered patches of this plant appear over much of the eastern half of the state of Washington. It has spread into Idaho, western Montana, Oregon, California, and the intermountain regions of Canada, and has been reported as far south as Flagstaff, Ariz. Although it is a short-lived perennial plant, it is an abundant seed producer that seems to be well adapted to droughty soils found on western rangelands (Robocker, Gates, and Kerr, 1961). In certain areas dalmatian toadflax has moved onto sites vacated when Klamath beetles (*Chrysolina quadrigemina* Suffr.) suppressed St. Johnswort (*Hypericum perforatum* L.) (Lange, 1958). Dalmatian toadflax has very low potential as a forage plant. Most classes of livestock refuse to eat it.

Gates and Robocker (1960) noted that soil disturbance was necessary for establishment of Dalmatian toadflax. Robocker et al. (1961) and Robocker (1968) found that combination of 2,3,6-trichlorobenzoic acid (2,3,6-TBA) or a mixture of 2-(2,4,5-trichlorophenoxy)propionic acid (silvex) and 4-amino-3,5,6-trichloropicolinic acid (picloram) and disking reduced survival of toadflax and improved conditions for establishment of Siberian wheatgrass [*Agropyron sibericum* (Willd.) Beauv.]. Chemical control alone at present is impractical except for small infestations. Since seedlings of Dalmatian toadflax do not become established in vigorous, competing vegetation, control programs must be centered about improvement of stands of perennial forage plants either through seeding or improved grazing management.

II. POISONOUS PLANTS

Poisonous plants kill from 3 to 5% of the cattle, sheep, and horses on western rangelands each year (USDA, 1968). In addition, they cause unmeasured harm due to sublethal doses that result in unthrifty condition, abortion, and under-use of ranges (Cronin, 1971). Losses may be severe and spectacular, such as those due to halogeton [*Halogeton glomeratus* (M. Bieb.) C. A. May.] or sporadic, such as an occasional death, often attributed to unknown causes as reported by the livestock operators.

Many publications are available that deal with poisonous plants of the western range. They vary from comprehensive lists (Kingsbury, 1964; Schmutz, Freeman, and Reed, 1968) to those that deal with species that are most important to a certain geographic area (USDA, 1968, Williams and Cronin, 1966). Tall larkspur, halogeton, St. Johnswort, and timber milkvetch are four species that illustrate the different kinds of problems confronting the livestock operator and the kinds of control measures available to him.

A. Tall Larkspur

Tall larkspur (*Delphinium barbeyi* Huth) causes severe financial loss to cattle ranches on mountain ranges, particularly on the Wasatch Plateau of Central Utah (Cronin, 1971). It grows at elevations ranging from 1,800 to 3,300 m; dense stands occur mainly on sites where snowdrifts accumulate during the winter. The toxic substances in tall larkspur are alkaloids, with concentration highest during early vegetative growth (Williams and Cronin, 1966). Young leaves and apical growing points contain the highest concentration of alkaloids. Alkaloid content decreases rapidly until flowering and then decreases more slowly.

Tall larkspur can be selectively controlled with applications of silvex or 2,4,5-T at 4.5 kg/ha in 2 or more successive years in Utah (Cronin, 1971). Torell and Higgins (1963) recommend an aqueous spray of a low volatile ester of 2,4,5-T at concentration of 0.96 g/liter applied to point of runoff to control duncap larkspur (*D. occidentale* S. Wats.) in Idaho. Treatments should be applied after all stalks have emerged but before the flowering stalk emerges. When tall larkspur was controlled, perennial forage grasses increased on the treated areas. At least a threefold increase in forage was obtained in both the Idaho and Utah studies. Tall larkspur plants treated with either silvex or 2,4,5-T contained significantly higher concentrations of alkaloids than untreated plants (Williams and Cronin, 1963). To avoid toxic plants and to permit forage grasses to increase in numbers and vigor, treated areas should not be grazed during the season of treatment.

Chemical control of tall larkspur can be costly when calculated on the basis of cost per unit area treated; however, when the severity of losses is considered, these costs should be considered a part of the maintenance for the entire allotment. For example, on a 3,200-hectare allotment only 139 hectares were infested with tall larkspur. Average annual losses due to tall larkspur poisoning on the allotment were estimated to be in excess of $14,000. Since only the infested areas need to be treated to prevent death and other losses, costs as high as $100 per hectare can be justified (Cronin, 1971).

B. Halogeton

Halogeton has caused severe sheep-kills during the past 25 years (Sorensen, 1971). Heavy losses have occurred when hungry animals were trailed or bedded on heavily infested areas or penned in corrals containing dense stands of halogeton. Cattle may be affected by this plant, but large losses have not occurred as in the case of sheep. The toxic substances in halogeton are sodium and potassium oxalates. They constitute from 17 to 30% of the dry weight of halogeton, depending upon the time of the year (Dye, 1956; Morton, Haas, and Erickson, 1959).

This plant is most apparent along roads, sheep trails, bed grounds, and areas where the soil has been disturbed and the native plant cover removed. Halogeton has invaded more than 4 million ha of desert rangeland in the western U. S. It produces large numbers of seeds that germinate from mid-February to mid-August. Plants established during this period can produce a seed crop before the growing season ends in October. Both black and brown seeds are produced. The black seeds lost viability within 2 years, while brown seeds buried in soil retained viability for 10 years (Robocker et al., 1969). It is not practical to attempt eradication of halogeton because of the large numbers of seeds produced and because the low value of the land would not support the cost. Small infestations can be controlled by treatment between June 20 and July 10 with a low volatile ester of 2,4-D in water at a rate of 2.2 kg/ha. After July 10, when the plants begin flowering, treatment should utilize a spray containing low volatile ester of 2,4-D at 4.5 kg/ha in diesel oil. Spraying will injure native shrubs that provide competition to halogeton. An assessment should be made on benefits of control vs injury to other vegetation. Management of ranges should be aimed at maintaining vigorous, perennial vegetation that will prevent halogeton invasion.

C. St. Johnswort

St. Johnswort (*Hypericum perforatum* L.), sometimes called goatweed or klamathweed, is an introduced perennial weed that occurs on western rangelands from California to British Columbia. It contains the poisonous substances hypericin and hypericum red, which cause white areas of the skin to develop severe sunburn when exposed to direct sunlight. Cattle and sheep are most often affected but almost all white-skinned animals may be poisoned. It seldom kills livestock but does cause severe economic losses. In addition to poisoning livestock, St. Johnswort reduces productivity of ranges by crowding out forage grasses and reducing the utilization of forage.

Large acreages of St. Johnswort have been controlled with Klamath beetle; this method of control should be used wherever extensive infestations exist. Fair control of St. Johnswort in small patches can be obtained with 2,4-D at a rate of 3 kg/ha.

After St. Johnswort has been controlled and desirable plants have increased in density, the rangelands are more productive. However, dalmatian toadflax has invaded some of the ranges on which St. Johnswort has been controlled (Gates and Robocker, 1960). The interaction of St. Johnswort and dalmatian toadflax on rangelands illustrates the futility of controlling weeds on rangelands without insuring that desirable vegetation replaces the controlled weed. In addition to weed control measures and reseeding with desirable forage plants, proper livestock management should be practiced to insure vigorous growth of the forage crop.

D. Timber Milkvetch

Timber milkvetch (*Astragalus miser* Doug. ex Hook.) grows at elevations ranging from 1,800 to 3,350 m on rangelands extending from British Columbia to northern Mexico. The severest cattle losses caused by this poisonous plant have occurred in northern Utah and British Columbia. Plants are poisonous from the time they emerge in the spring until they dry up in the summer or are killed by frost in the fall. Three varieties *oblongifolius, serotinus,* and *hyophilus,* out of the eight that have been classified contain relatively high concentrations of miserotoxin, the toxic substance (Williams and Norris, 1969). Because the five other varieties that are not toxic also occur on western rangelands, there has been considerable confusion about the identity and toxicity of timber milkvetch. As a consequence, many livestock deaths caused by timber milkvetch have been attributed to poisoning by other plants such as tall larkspur or to unknown causes.

Timber milkvetch emerges soon after snow melts, and flowers in June and July. It grows mostly on open well-drained meadows. When leaves and stems lose their green color they are not poisonous. Plants can be killed by treating with esters of 2,4,5-T or silvex at 2.24 kg/ha before plants reach full bloom. Those treated with silvex or 2,4,5-T lose their toxic properties rapidly. Four weeks after treatment, treated plants contain one-third as much miserotoxin as untreated plants. A most effective method of eliminating death losses is to treat with silvex or 2,4,5-T and defer grazing until the plants have dried up and lost their green color.

III. WOODY PLANTS

Brush species occupy an estimated 130 million ha of western rangeland. Not all ranges supporting brush are dominated by the brush species and on many the potential productivity is insufficient to justify cost of control measures. However, brush invasion has meant reduced productivity of forage plants, increased cost of handling livestock, increased damage from parasites, reduced calf and lamb crops, and higher losses due to predators.

Invasion of brush has had a detrimental effect on the environment. Brush crowds out grasses and other herbaceous plants and leaves the ground exposed to soil erosion from wind and water, which reduces the quality of water and increases sedimentation in ponds and lakes. Deeply rooted woody plants reduce yield of water from watersheds and underground water supplies.

Some species of brush provide valuable browse and a desirable habitat for wildlife. Thick stands, however, prevent the growth of herbaceous browse plants and grasses essential for the varied diet required by most animal species. Thick stands of brush also make wildlife inaccessible to the hunter and in other ways reduce the recreational value of land.

Many areas supporting dense stands of brush are potential fire hazards. If these plants are permitted to grow unchecked, litter accumulates to a depth sufficient to support fires in the dry season. Fires from these could endanger animal life and remove protective vegetation that prevents flooding and soil erosion.

A. Mesquite

Mesquite infests about 28 million ha in the southwestern states of Arizona, New Mexico, Oklahoma, Texas, Nevada, and California. Three varieties occur in the United States: honey mesquite [*Prosopis juliflora* var. *glandulosa* (Torr.) Cockerell]; velvet mesquite [*P. juliflora* var. *velutina* (Woot.) Sarg.]; and western honey mesquite (*P. juliflora* var. *torreyana* L. Benson) (Fisher et al., 1959). Honey mesquite occurs for the most part north and east of the Rio Grande River. Velvet mesquite is the main variety in Arizona, western New Mexico, and lower California. Western honey mesquite occurs in southern California, western Arizona, southern New Mexico, and parts of western Texas.

The primary objective in controlling mesquite on grazing lands is to increase the density, vigor, and productivity of perennial forage plants; however, secondary benefits from control are the greater ease of managing livestock and reducing wind and water erosion. Mesquite is spread primarily by seed. The intact seed has a low germination rate, but after mechanical or chemical scarification germination of 90% or greater is not uncommon. Seed can remain viable for at least 20 years (Martin, 1971).

Thin to open stands (less than 250 plants/ha) of mesquite can be controlled economically by treatment of individual plants, which is recommended in areas where mesquite seedlings are invading.

Grubbing is an effective method of killing plants with stems less than 2.5 cm in diameter. Thin stands of single to few-stemmed trees can be killed by pouring or spraying diesel oil or kerosene around the base of the tree. Dense stands of mesquite with stems of 7.5 cm or more in diameter can be controlled by cabling and chaining.

Stands of all size classes can be controlled by aerial application of foliage sprays of 2,4,5-T. Tops of most plants of honey mesquite are killed with one application of low volative ester of 2,4,5-T at 0.3 kg/ha (Fisher et al., 1959). Stands usually recover in 5 to 7 years and need retreatment. To control velvet mesquite two treatments should be applied, 1 or 2 years apart depending upon effectiveness of the first treatment and refoliation of the trees after treatment (Reynolds and Tschirley, 1963). Foliage sprays are most conveniently applied with aerial equipment. Small trees, sprouts, and seedlings can be controlled with drenching sprays of herbicides.

B. Oak-Chaparral

Oaks (*Quercus* spp.) are a large diverse group of plants that occupy several million hectares of rangeland in the western United States. Their growth habit varies from large trees (Fig. 1) to small shrubs (Fig. 2). While there are many species of oak, the most common and troublesome include: Gambel oak (*Q. gambelii* Nutt.); sand shinnery oak (*Q. havardii* Rydb.); shrub live oak (*Q. turbinella* Greene); blue oak (*Q. douglasii* Hook. and Arn.); interior live oak (*Q. wislizenii* A. DC.); live oak (*Q. virginiana* Mill.); post oak (*Q. stellata* Wangenh.); and blackjack oak (*Q. marylandica* Muenchh.). Forage production beneath heavy oak canopy is usually very limited. Shrub oaks often form impenetrable thickets that not only reduce forage production, but also increase the cost of managing livestock. Some oaks, particularly Gambel and shinnery oaks, are poisonous to livestock; however, they also provide browse and mast for deer and wild turkey. Oak trees provide shade for livestock and are esthetically pleasing when growing in savannahs on rangeland areas.

Oak trees can be controlled with a number of methods (Darrow and McCully, 1959). The choice of method will depend on the species, stand density, growth form, and equipment available. Thin stands can be controlled with the tree injector (Fig. 3), felling the tree and treating the stump with ammonium sulfamate (AMS), or placing AMS or 2,4,5-T in ax frills cut near the base of trunk. Ex-

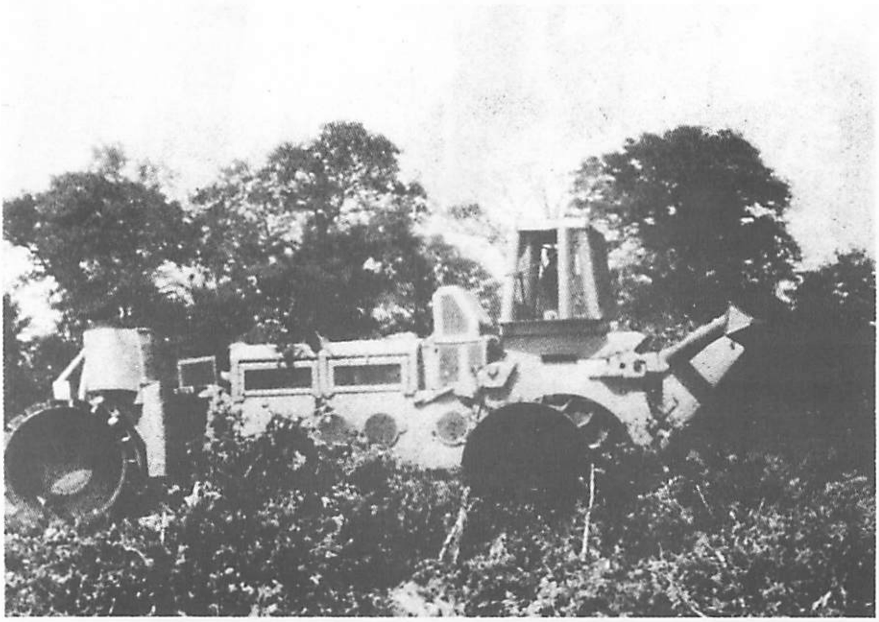

Fig. 1–Tree crusher pushing down large post oak trees. Lugs on wheels cut stems and branches. This machine does not kill root-sprouting plants.

Fig. 2–Dense stand of oak-chaparral reduces forage production, increases the cost of managing livestock, and reduces water yield of watersheds.

Fig. 3—Tool used to inject herbicides into the stems of woody plants. The chisel on the lower end of the tool has a hole in the center through which herbicide is injected after the chisel is driven into the stem.

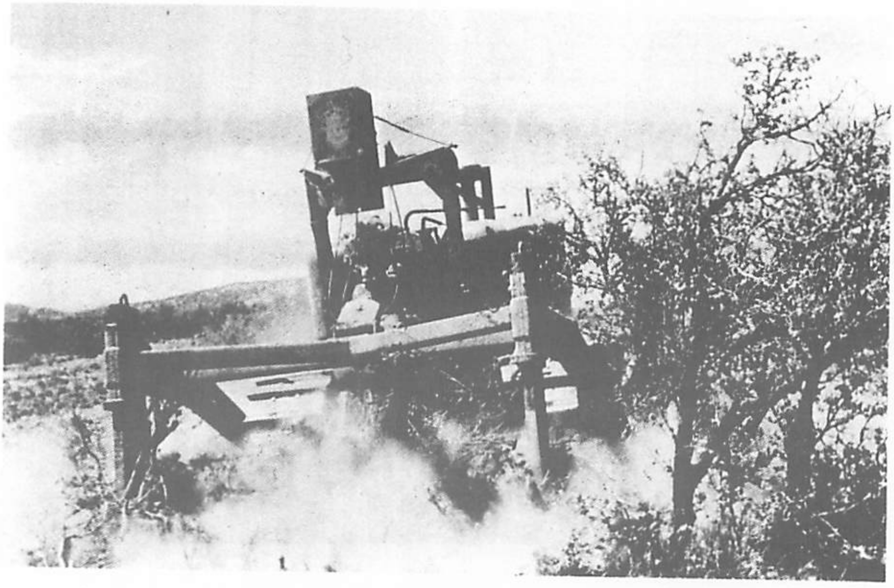

Fig. 4—Tractor pulling rootplow through oak-chaparral. Seed hopper mounted on tractor distributes forage seed on disturbed soil.

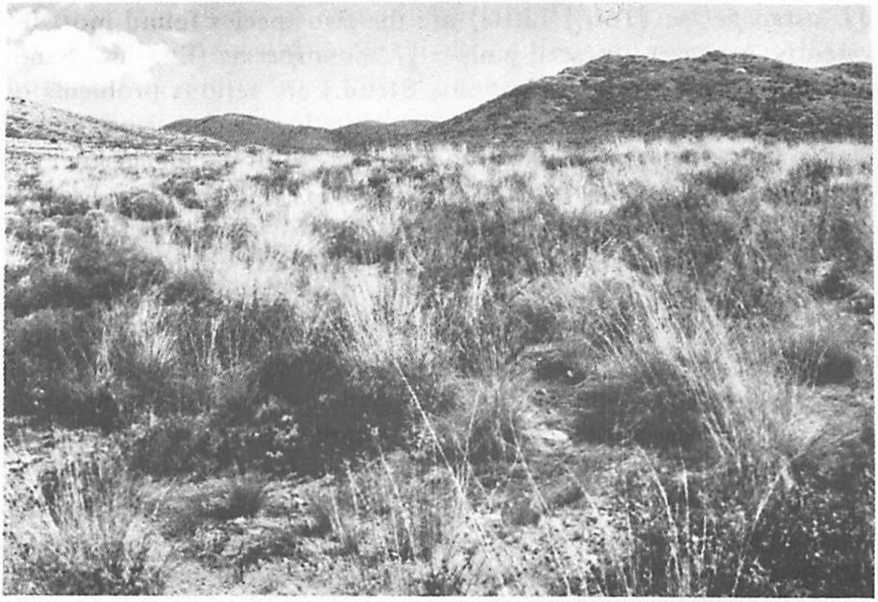

Fig. 5—Oak-chaparral on this site was burned and reseeded to weeping lovegrass. It was treated with 2,4,5-T at 1.87 kg/ha the third year after burning to control the oak. Forage grass yield was 1,350 kg/ha.

tensive areas with dense stands can best be controlled with aerial application of herbicides, chaining, or other methods utilizing large equipment. Infested areas with few forage plants can be rootplowed and reseeded (Fig. 4).

Elwell (1964) found that aerial treatment of post and blackjack oak stands in Oklahoma with esters of 2,4,5-T resulted in a threefold increase in forage production in years with above-average rainfall and at least a sixfold increase in years with below-average rainfall. Johnson et al. (1959) obtained a fivefold increase in annual forage produced after cut surface treatment of interior live oak in California. Schmutz and Whitham (1962) found that repeated application of 2,4,5-T at 1.87 kg/ha for 3 consecutive years to a burned and reseeded oak chaparral area in Arizona gave an increase in forage production of more than 1,100 kg/ha (Fig. 5).

C. Juniper

Junipers, cedars, and red cedars are widely distributed on about 30 million ha of rangeland in the western United States. Rocky mountain juniper (*Juniperus scopulorum* Sarg.) and Utah juniper

[*J. osteosperma* (Torr.) Little] are the two species found most frequently; however, oneseed juniper [*J. monosperma* (Engelm.) Sarg.] and alligator juniper (*J. deppeana* Steud.) are serious problems on rangelands in certain areas. Juniper plants invade rangelands and reduce the yield of forage plants and interfere with the management of livestock (Johnsen, 1962).

The method of juniper control to be used will be determined by the stand density, site, and equipment available. For open stands of single and few-stemmed plants of juniper that do not sprout from the base of the trunk or roots, cutting the juniper for posts is a practical method of control. Not only does the method kill the plants, but it also yields valuable fence posts that can be used by the landowner or sold. On denser stands of even aged juniper, chaining or cabling is effective. On uneven aged stands, young plants are not killed. Burning and reseeding can also be effective in increasing the productivity of rangelands infested with juniper (Fig. 6). Burning requires enough fuel to carry a hot fire and safety precautions should be taken to prevent a "wild fire." Burning may cause undesirable air and water pollution and is now regulated by pollution control agencies in many states. Runoff water from burned rangelands may be ladened with

Fig. 6—Utah juniper was burned followed by seeding with crested, intermediate, and western wheatgrass at Cedar Mesa, Apache Indian Reservation, Ariz.

sediment and plant nutrients and care should be exercised to see that water from the burned site does not pose a threat to downstream lakes, streams, and flood plains.

Alligator juniper sprouts from the trunk and roots; thus, control is effective only if the roots are killed. Mechanical methods of control such as chaining or cutting are usually not effective. Treatment of the stumps with polychlorobenzoic acid (PBA) or soil application with PBA or 1,1-dimethyl-3-phenylurea (fenuron) will prevent resprouting of alligator juniper (Jameson and Johnsen, 1964).

D. Sagebrush

One of the major resource areas of the west is the sagebrush-grass type. Sagebrush occurs on about 109 million ha in all of the 11 western states (Beetle, 1960). Big sagebrush (*Artemisia tridentata* Nutt.) communities are extensive and occupy about 39 million ha, which includes many sites having a very high potential for forage production.

On a large part of this area sagebrush is relatively dense and must be reduced before appreciable increases in forage yield can be realized. Sagebrush control is important on ranges used primarily for grazing by livestock. Sagebrush competes with forage grasses, prevents livestock from grazing grasses hidden under plants, hampers the movement of livestock, causes lambs and calves to stray and become lost, and creates an ideal environment for predators of livestock (Pechanec et al., 1965).

On some ranges, especially those used for winter range, sagebrush control may not be useful, because certain species such as blacksage (*A. nova* A. Nels.) and budsage (*A. spenescens* D. C. Eaton) are valuable forage plants.

There are several methods for controlling sagebrush. The decision as to which method, if any, should be used should be based on the species to be controlled, the presence or absence of desirable forage species, the productive potential of the site, and the equipment available to the land manager. Large dense stands of sagebrush usually indicate sites with good soils, good rainfall, and high forage potential. Scattered, short stands of sagebrush usually indicate poor soils with low rainfall and low forage potential.

Sagebrush has been controlled by burning, applying various mechanical treatments, and spraying with herbicides.

Planned burning is one of the oldest methods of sagebrush control. When properly done, it may kill from 95 to 100% of the sagebrush (Pechanec et al., 1965). Not all sites are suitable for burning and proper precautions must be taken to control the fire. Burned sites are usually reseeded with desirable forage species if the terrain is not too rough. Cost of burning is extremely variable, ranging from \$1 to \$12/ha.

Plowing or disking is an effective method of controlling sagebrush, but it is not adapted to rocky or rough terrain. Plowing or disking kills 70 to 90% of sagebrush plants and simultaneously prepares a seedbed for establishing desirable plants. The cost ranges from \$12 to \$24/ha. Sites must be reseeded after disking, since desirable plants are also destroyed.

Anchor chaining, cutting, beating, and shredding and harrowing are mechanical methods that kill from 50 to 90% of old, rigid plants, but are ineffective on young flexible plants. These methods do not kill sprouting shrubs and most herbaceous plants. Anchor chaining and harrowing are suitable for use on rocky, rough terrain, but cutting, beating, or shredding is unsuitable for sites with protruding rocks. Cost varies from \$2.50 to \$20.00/ha, depending upon the terrain, size of site, rockiness, density of brush, and number of times the equipment must be pulled over the site.

Spraying with 2,4-D usually kills from 50 to 99% of the sagebrush plants. Applying from 1.1 to 2.2 kg/ha of an ester formulation of 2,4-D in 45 to 95 liters of water gives satisfactory control when applied at the proper time. Spraying should be started when small bluegrasses (*Poa* spp.) are heading out and stopped when the bluegrasses lose green color and the surface 30 cm of soil is dry.

Where stands of perennial grass are inadequate, seeding crested wheatgrass with the rangeland drill in the fall of the year of treatment without seedbed preparation usually has been successful. If seeding is delayed until the second fall after spraying, dense stands of downy brome will have become established.

The length of time a sagebrush control method will be effective depends on the degree of the initial kill, the intensity of grazing, the density of forage plants, and the kind of management system. Johnson (1969) found that in central Wyoming sagebrush plants began to increase in size and numbers within 5 years after spraying and the increased herbage production was nullified in 6 years. A Colorado study (Anon., 1961) showed that beef production increased 36.6 kg/ha annually over an 8-year period after sagebrush control.

E. Cactus

Most cacti of economic importance on rangelands are members of the genus *Opuntia*. Engelmann pricklypear (*O. engelmannii* Salm-Dyck), Lindheimer pricklypear (*O. lindheimeri* Engelm.), and plains pricklypear (*O. polyacantha* Haw.) are the most important pricklypear cacti. Jumping cholla (*O. fulgida* Engelm.), spiny cholla [*O. spinosior* (Engelm. and Bigel.) Toumey], and staghorn cholla (*O. versicolor* Engelm.) are the most abundant cholla cacti.

Pricklypears occur on rangelands in all western states, but are most abundant on ranges of the Southwest and the Great Plains. Chollas occur primarily in southern Arizona, New Mexico, and western Texas. These spiny plants occupy space, compete with forage plants for water and nutrients, and impair the handling of livestock.

Many cacti are considered to be valuable ornamentals. Fruits and seeds serve as an important source of food for birds and other forms of wildlife, and livestock operators frequently use cactus as an emergency source of feed during drought periods. Because of these conflicts of interest, it has not been thought prudent to introduce the insect *Cactoblastus cactorum* into the United States for control of pricklypear. This insect was very effective in Australia and some other countries.

Pricklypear cacti can be controlled by hand grubbing, railing, prescribed burning, or chemical treatment. Hand grubbing of plants in light soils is effective if the main root is severed 5 to 10 cm below soil surface. After grubbing, plants should be piled and burned. If pads are permitted to remain on moist soil, they will take root and form dense stands in a few years. Pulling a large railroad iron two ways over pricklypear uproots the plants, which can then be used as feed for livestock.

Scattered stands of cholla cactus can be effectively controlled by hand chopping or sawing, piling the plants and burning. Dense stands may be controlled by cabling or chaining (Fig. 7). Herbicidal control of cholla on large areas is not economically feasible. On small acreages or scattered plants, however, an ester of silvex or 2,4,5-T applied over the entire plant to the point of runoff is effective (Wicks, Fenster, and Burnside, 1969).

Burning is sometimes an effective method of controlling both cholla and pricklypear. Burning removes the spines and livestock can eat the pads without injury.

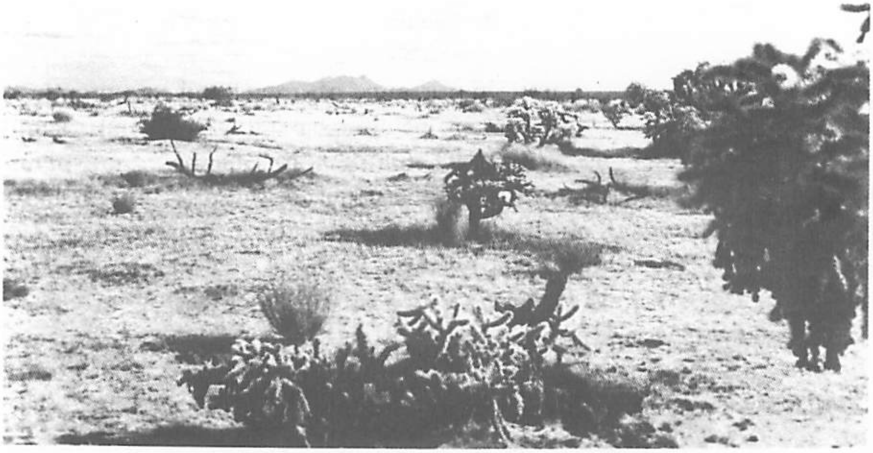

Fig. 7—Chaining has killed many jumping cholla cactus (left) and opened up this pasture so that forage is more accessible and grazing animals are more easily managed. Untreated area on right.

IV. SUMMARY AND CONCLUSIONS

Weeds and brush cause losses estimated at $250 million annually on western rangelands. These losses are related to reduced productivity of forage plants, livestock poisoning, increased cost of handling livestock, and lower calf and lamb crops. Losses can be reduced through a variety of control measures, including hand grubbing and spraying, chaining, railing, beating, burning, plowing, disking, and aerial spraying when combined with improved grazing management.

Control of weeds and brush is essential on many sites now dominated by weeds and brush before further improvement of the range is possible. Range improvement involves an integrated program of adequate weed and brush control and efficient management practices that include reseeding and proper grazing of the land.

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