High Technology Weed Control-- Revegetation Systems for Establishment and Maintenance of Crested Wheatgrass

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ABSTRACT: Large areas of sagebrush-grass rangelands are brush dominated and are producing 50 percent or less of their forage potential. Conversion of these rangelands to crested wheatgrass for increased forage production involves brush and weed control and seeding. Application of herbicides, either by air or ground sprayer, controls brush and weeds effectively and economically. Systems that combine herbicide spraying for brush and weed control with seeding by rangeland drills of crested wheatgrass and other forage species have been developed and shown to be effective for improvement of degraded sagebrush rangelands. Periodic spraying of brush may be necessary to maintain high forage productivity of the established crested wheatgrass.

INTRODUCTION

Development of equipment and techniques for seeding large areas of western rangelands to crested wheatgrass (Agropyron cristatum and A. desertorum) has been discussed (see Young and Evans in this proceedings). Our intent in this paper is to present the most modern technology in plant control and revegetation systems now available to range managers. From the historical basis of mechanical brush control we will emphasize development and use of herbicides and spraying technologies.

The Problem

The sagebrush-grass ecosystem is the largest rangeland type in the western United States. In the Great Basin and Northwest subregion, which includes most of northern Nevada and parts of Utah, Idaho, Oregon, and Washington, there are almost 85 million acres (35 million ha) of sagebrush-grass rangeland (Evans et al. 1981). Of these rangelands, 88 percent or almost 75 million acres (30 million ha) are degraded to the point that they are producing 50 percent or less of their forage potential (Forest Service 1972). Only 1 percent of the over 4 million acres in the Humboldt River Basin of northeastern Nevada are in the high forage production class (Anonymous 1966). Low forage production on these rangelands has been caused by overgrazing and other past land abuses (Young et al. 1979), resulting in a severe depletion of native perennial grasses, a dominance of brush, and in many instances an annual alien weed dominance in the understory.

Once big sagebrush (Artemisia tridentata) becomes established as the dominant species of degraded sagebrush-grass rangelands, it is persistent enough to stabilize succession in these communities for long periods. The tenure of dominance has not been determined, but the life expectancy of big sagebrush may exceed 150 years (Ferguson 1964). Degraded rangelands dominated by big sagebrush can remain static, producing virtually no forage for decades regardless of grazing management or even without livestock grazing.

By far the most abundant brush species of the sagebrush-grass rangelands is big sagebrush with its three subspecies: basin (A. t. ssp. tridentata), Wyoming (A. t. ssp. wyomingensis), and mountain (A. t. ssp. vaseyana). On specific sites other species of sagebrush dominate, e.g., low sagebrush (A. arbuscula) and early sagebrush (A. longiloba) usually occur on shallow soils with an argillic horizon, black sagebrush (A. nova) usually is associated with carbonate soils, and silver sagebrush (A. cana) is found primarily on sites with impounded drainage.

Representing seral stages after disturbances, and on many sites occurring as either codominant or subdominant with big sagebrush, are green and gray rabbitbrush (Chrysothamnus viscidiflorus and C. nauseosus) and horsebrush Tedradymia canescens). Other brush species occurring in some stands are species of Ribes, Ephedra, and Prunus.

The Solution

To improve these brush-dominated rangelands for increased livestock production, the first consideration is the control of brush. The second is, on some sites, the control of herbaceous weeds, and the third is replacement of brush and weeds by

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forage species. Historically and at the present time, the most widely adapted forage species for seeding on sagebrush rangelands is crested wheatgrass. Development of other grasses, broad-leaved plants, palatable shrubs, and seeding mixtures of forage and browse broadens the spectrum of available replacement vegetation. An array of plant species not only increases environmental adaptability of replacement vegetation, but widens their use by domestic livestock and wildlife. The latter consideration is becoming increasingly important as society puts more and more demands on the multiple use of rangelands.

BRUSH CONTROL WITH HERBICIDES

What to Spray

The discovery of 2,4-D [(2,4-dichlorophenoxy) acetic acid] as a plant growth regulator in 1942 began the development of synthetic hormones for weed control (Bovey 1971). After World War II, several scientists independently recognized the potential of 2,4-D in controlling sagebrush for the release of perennial grasses. This herbicide is currently registered by the Environmental Protection Agency (EPA) for use on sagebrush-grass rangelands.

Among the first to demonstrate the effectiveness of 2,4-D for controlling big sagebrush were Elwell and Cox (1950), Cornelius and Graham (1951), and Hull and Vaughn (1951). Later, the usefulness of 2,4-D was demonstrated by Hyder (1953) in eastern Oregon, and by Hull et al. (1952) and Bohmont (1954) in Wyoming.

Gradually, guidelines were developed to help ensure the success of spray application. As the brush control program with 2,4-D became widespread, there were a few failures, almost all of which can be traced to violations of the initial guidelines. Additional research is warranted on improving the efficacy of 2,4-D for brush control. Improved application technology is needed for equipment modifications; use of different total volumes of spray and improved surfactants, additives and carriers; and the use of remote sensing to more accurately predict the periods of optimum susceptibility.

Although 2,4-D effectively controls sagebrush, other brush species either occurring alone or in mixed stands with sagebrush are more resistant to this herbicide. Effective control of green rabbitbrush by 2,4-D requires careful timing of application in relation to its phenology and to air temperature and available soil moisture. In some years, 2,4-D does not adequately control green rabbitbrush or the period of susceptibility is so short that only small areas can be treated. These problems have been lessened by the use of more recently developed herbicides that translocate better.

The most effective and widely tested of the alternative herbercides has been picloram (4-amino-3,5,6-trichloropicolinic acid). Relatively low rates of picloram have been shown to be extremely effective for control of green rabbitbrush (Cook et al. 1965, Tueller and Evans 1969). Picloram does not control big sagebrush at these rates, so 2,4-D must be applied with the picloram for control of both species. Picloram has not been marketed as a mixture with low-volatile esters of 2,4-D. Tank mixtures of potassium salts of picloram and low-volatile esters of 2,4-D have been effective in aerial applications to mixed stands of green rabbitbrush and big sagebrush (Evans and Young 1975). Picloram has been registered by EPA for application either alone or in tank mixtures with 2,4-D for control of rabbitbrush and other brush species on rangelands with a Special Local Needs Label for Idaho, Nevada, Oregon, Utah, and Washington. A Supplemental Use Label has been issued for control of weed and brush species, including rabbitbrush, in Wyoming.

Tebuthiuron [N-[5-1,1-dimethylethyl-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea] and dicamba (3,6-dichloro-anisic acid) are both registered for brush control on rangelands by EPA but there are very few publications verifying their efficacy on sagebrush-grass rangelands. Britton and Sneva (1981) indicated that frequency of occurrence of sagebrush was severely reduced with 1.8 lb/A (2 kg/ha) of tebuthiuron (20 percent a.i. pellets). Big sagebrush was virtually eliminated by 3.6 lb/A (4 kg/ha). At these rates, associated perennial grasses were also damaged.

Further studies in Oregon with tebuthiuron at lower rates indicate 80 percent control of big sagebrush with 0.87 lb/A (1 kg/ha), 58 percent with 0.75 lb/A (0.8 kg/ha), and 35 percent with 0.5 lb/A (0.6 kg/ha) of the 20 percent a.i. pellets, respectively (unpublished data, R. Miller, USDA-ARS, Burns, OR). No significant damage was seen on perennial grasses when tebuthiuron was applied at these rates. Cooperative studies among Elanco (chemical company marketing tebuthiuron), the Bureau of Land Management, and ranchers are being conducted in many areas to evaluate the efficiency of tebuthiuron for brush control.

It must be kept in mind that tebuthiuron is a wide-spectrum, soil-active herbicide which will persist over several years, so its use for brush control preparatory to seeding of crested wheatgrass cannot be considered. Its best use will be control of sagebrush in established stands of crested wheatgrass and other perennial grasses.

At this time, 2,4-D is the most practical herbicide for brush control on sagebrush-grass rangelands. Big sagebrush is usually controlled by 2 lb/A (2.2 kg/ha) of low-volatile esters of 2,4-D. With mixed stands of sagebrush and green rabbitbrush, control can be effective with either 3 lb/A (3.4 kg/ha) of 2,4-D or a mixture of 1/2 lb/A (0.6 kg/ha) of picloram and 2 lb/A (2.2 kg/ha) of 2,4-D.

When to Spray

Big sagebrush is most susceptible to 2,4-D when it is growing rapidly in the spring. Because big sagebrush has persistent leaves, however, its phenology is difficult to measure. Hyder (1954) used the phenology of a native perennial grass, Sandberg bluegrass (*Poa secunda*), to estimate the correct time for applying 2,4-D. He concluded that the best time for spraying in eastern Oregon extended from the heading of Sandberg bluegrass until one-half of the green color was gone. Measurements of soil moisture have been found to be important in estimating the correct time for herbicide application, generally in the month of May. However, on shallow soils or south slopes, the correct application time may be earlier and of much shorter duration; in wet years it may be later and of much longer duration. In Wyoming, a more reliable way of estimating the correct timing of herbicide application is based on the phenology of big sagebrush itself (personal communication from H. P. Alley).

As previously noted, species of rabbitbrush are more difficult to control with 2,4-D than big sagebrush. Hyder et al. (1958) and Hyder and Sneva (1962) determined that application must be carefully timed for adequate control of rabbitbrush. Current annual growth of shoots must reach 3 inches (7.6 cm) and soil moisture must be available for effective herbicidal action. The length of time that green rabbitbrush is susceptible to 2,4-D varies greatly among years and locations. The period of susceptibility may equal that of big sagebrush or it may not occur at all.

In mixed stands of big sagebrush and rabbitbrush, herbicide application should be timed with the phenology of rabbitbrush because of its usually shorter period of susceptibility. When determining date of spray of both big sagebrush and rabbitbrush, measurements of available soil water are important. Roundy et al (1983) recently published methods of measuring soil water on rangelands which should prove useful to the range manager.

Prediction of the optimum date for application of 2,4-D to green rabbitbrush is essential because herbicide-mixing facilities, aircraft, and flagging crews must be prepared in advance if they are to be ready by the chosen date at the often remote sites. Prediction is complicated by the phenology pattern of growth for green rabbitbrush, in which 40 percent of the current year's growth can occur within 2 weeks before the optimum application date (Young and Evans 1974). Prediction is further complicated by the interaction of age and competition on the growth rate and phenology of green rabbitbrush. Young stands grow faster than old stands that are competing with big sagebrush plants.

Color infrared photographs can be used to predict the optimum spray date for green rabbitbrush (Evans et al. 1973, Young et al. 1976). This method has the advantage of enabling the collection of large, statistically precise samples from remote areas in a very short time. A single trained interpreter can predict the optimum application date from photographs and return a recommendation within 24 hours.

How to Spray

Aerial applications of 2,4-D are the most practical to control big sagebrush over large areas. Prevailing recommendations are to use 5 gal/A (47 L/ha) of water as a carrier for the 2,4-D. In the past, some range managers preferred diesel oil to water as a carrier, but the increase in efficiency of weed control seldom justified the increase in cost and associated environmental hazards. In an assessment of spraying for control of big sagebrush on the Vale project in southeastern Oregon, Heady and Bartolome (1977) concluded that no clear-cut advantage was gained by the use of oil as a carrier. However, many land managers and some scientists (personal communication from H. P. Alley) strongly believe that oil is a better carrier than water.

Errors made in spraying for big sagebrush control include improper mixing of the herbicide and carrier, flying too high or too fast, and improper marking of sites to be sprayed during herbicide application (Pechanec et al. 1965). Such errors are probably less important than errors in the timing of spraying (personal communication from F. A. Sneva). A ground sprayer may be more practical to spray small areas, or to treat places remote from agricultural areas where aerial applicators may be difficult to obtain. Young et al. (1979) have modified readily available power-ground sprayers to permit their use on sagebrush rangelands

HERBACEOUS WEED CONTROL

On sagebrush rangelands, control of herbaceous weeds to allow the establishment of seedlings of desirable perennials is predominantly the control of alien annuals. The secondary successional role of native herbaceous species has been almost entirely preempted by downy brome (*Bromus tectorum*) and associated alien species (Piemeisel 1938).

Sites that have burned or otherwise had brush removed and are dominated by downy brome are largely closed to the establishment of perennial grass seedlings (Robertson and Pearce 1945). Attempts to introduce wheatgrasses on such sites by seeding generally have failed unless the sites were first fallowed by mechanical methods (Hull and Holmgren 1964).

The alien annual grass, medusahead (*Taeniatherum asperum*) has invaded portions of Oregon, California, Washington, and Idaho (Young and Evans 1970). Medusahead invasion on sagebrush rangelands is largely restricted to low sagebrush sites (Young and Evans 1971).

Paraquat

The herbicide paraquat (1,1'dimethyl-4-4'-bipyridinium ion) was evaluated for downy brome control because of its relatively unique characteristic of being deactivated upon adsorption to soil particles. This characteristic permits the spraying of paraquat at 0.5 to 1 lb/A (0.6 to 1.1 kg/ha) and the immediate seeding of wheatgrass (Evans et al. 1967). Paraquat is registered by EPA for downy brome control on sagebrush rangelands, but is a restricted-use herbicide because of its high mammalian toxicity. Proper care must be exercised in its use.

If the annual community being treated with paraquat contains tumble mustard (*Sisymbrium altissimum*), it is necessary to add 2,4-D at 0.5 lb/A (0.6 kg/ha) for control of this species. Paraquat, a contact herbicide, must be applied after the downy brome has emerged. On sagebrush rangelands, when fall emergence has occurred, spraying and seeding can be done. Otherwise, it is necessary to delay these operations until spring.

Under the environmental conditions of sagebrush rangelands, it is difficult to consistently control downy brome with aerially applied paraquat even though ground applications are always effective. The addition of proper surfactants enhances the effectiveness of ground applications (Evans and Eckert 1965).

Atrazine Fallow

After evaluating large numbers of soil-active herbicides, Evans et al. (1969) determined that atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] was the best candidate for creating herbicidal fallows. The characteristics evaluated were the spectrum of weed control, consistency of performance among years, and amount of herbicide residue 1 year after application.

The atrazine-fallow technique was developed (Eckert and Evans 1967) and tested extensively (Eckert et al. 1974). Atrazine is registered by EPA for specific uses on sagebrush rangelands. It is applied at 1 lb/A (1.1 kg/ha) in the fall, creating a fallow field during the next growing season. The area is seeded to wheatgrasses 1 year after the herbicide is applied. The amount of herbicide residue that is present at the time of seeding is critical in the success of seedling establishment (Eckert et al. 1972, Eckert 1974). The atrazine-fallow technique controls medusahead as well as downy brome (Young and Evans 1971).

SEEDING OF CRESTED WHEATGRASS

The rangeland drill and its modifications make possible seeding of crested wheatgrass through standing dead sagebrush and on rocky uneven sites. Historical accounts of seeding technology on rangelands outline the evolution of equipment that has culminated in the present rangeland drill (see Young and Evans in this proceedings and Young and McKenzie 1982). A modified rangeland drill that makes deep furrows while drilling is discussed by Asher and Eckert (1973) and Young and McKenzie (1982).

While the use of a grain drill is practical on a few plowed or burned sites, the rangeland drill is almost synonymous with seeding crested wheatgrass. The use of herbicides for control of sagebrush as part of an economical technology for replacement of brush with grass is a reality only with the use of the specifically designed, heavy duty rangeland drill (Kay and Street 1961). On many sites, seedling success is enhanced by seeding in the bottom of furrows made with the modified rangeland drill which provides a favorable microenvironment (McGinnies 1959 and Evans et al. 1970). In the atrazine-fallow method for downy brome control, furrowing removes herbicide residues in the surface soil in the immediate vicinity of the growing seedlings (Eckert 1974).

Standard rangeland drills in tandem can be pulled by a 40-horsepower tractor in a non-brushy situation. A 60-horsepower tracklaying tractor is required to pull standard rangeland drills in tandem through standing dead brush. Less power is required to pull modified rangeland drills through brush than standard drills because of fewer, wide-spaced arms.

Weed Control-Revegetation Systems

For big sagebrush communities in which perennial grasses are depleted and downy brome has invaded the shrub understory, it is possible to combine in sequence 2,4-D and atrazine-fallow treatments, and seeding of crested wheatgrass (Evans and Young 1977). This system approach allows for control of brush and herbaceous weeds and seeding to obtain successful stands of a forage species in place of degraded plant communities. The system can be used by (a) applying atrazine in the fall and 2,4-D the next spring; (b) applying 2,4-D in the spring and atrazine the following fall; or (c) applying a mixture of both herbicides in the spring at an optimum date for brush control.

Atrazine fallows make excellent weed-free seedbeds for transplanting seedlings of desirable browse species (Christensen et al. 1974). Shrub transplanting can also be adapted to weed control systems of atrazine and 2,4-D, or integrated with seedings of perennial grasses for establishment of forage-browse combinations (Evans and Young 1977).

MAINTENANCE OF GRASS STANDS

Many crested wheatgrass seedings become infested with sagebrush and rabbitbrush within 5 to 10 years following establishment. Brush infestation, which may be as heavy as 20 to 25 percent crown cover, drastically reduces forage productivity of crested wheatgrass. Data are limited, but one estimate of reduction is that each 1 percent increase of sagebrush crown cover was equivalent to a decrease of 4.5 percent in forge production when crown cover varied from 0 to 22 percent (Rittenhouse and Sneva 1976).

Control of sagebrush and rabbitbrush in established crested wheatgrass stands constitutes a cost-effective range improvement technology because the established stand of forage plants will respond to a relatively inexpensive treatment.

In a 1981 economic study of range improvement costs from Nevada, Sonnemann et al. (1981) determined an aerial application cost of $9.00 per acre for 2,4-D brush control. The study contrasted this with a cost of $21.50 per acre for spray and drill and $41.80 per acre for plow and drill to establish crested wheatgrass on similar rangelands.

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