Ecological Characteristics and Control of Gambel Oak

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Abstract

Manipulation of Gambel oak for enhanced rangeland values must be in accord with ecological principles to ensure desired success. Failures in controlling Gambel oak have occurred because the growth patterns, morphological characteristics, and carbohydrate storage patterns of the species have not been taken into account. However, recurrent control will continue to be necessary since grass dominated systems should not be considered to be climax in Gambel oak dominated systems. Existing initial and maintenance control methods appear to offer only short-term solutions, which often result in more troublesome long-term management problems.

Gambel oak *(Quercus gambelii)* is considered a major brush problem species on millions of acres of foothill ranges in Colorado, Utah, New Mexico, and Arizona. Creating open grasslands by removal of mature stands of Gambel oak from these ranges increases watershed values and presents several advantages to the livestock producer (Marquiss 1972). The greatest benefits are an increase in forage produced for livestock and enhanced livestock handling. However, since Gambel oak is a natural part of the vegetation, recurrent treatment is required to retain these advantages.

Eradication of Gambel oak is rare by any method, and without complete kill prolific sprouting may occur from roots, rhizomes, and basal stems. Treated ranges many times assume a "thicket"-like appearance several years after an initial oak control effort. These sprout thickets differ from the original mature oak stands in both their structure and response to control methods.

Range managers are in need of effective control methods on these previously treated areas where abundant oak sprouts are difficult to control with conventional methods and present a major management problem. We suggest here some reasons for the difficulty in controlling Gambel oak and propose some possible alternatives for dealing with the Gambel oak sprouts.

Problems in Controlling Gambel Oak

Application of Ecological Principles

Range scientists recognize that proper and wise management of ranges includes direct manipulation of the ecosystem. Such manipulation should be directed in ways that work in accord with the natural functioning of ecosystems and should be based upon ecological principles, that is, particularly competition and succession (Vallentine 1971). With increasing costs of fuels and herbicides, conventional methods of manipulating oakbrush ranges must continue to be cost effective, as well as environmentally sound. Yet, the demand for meat by an expanding world population is sure to place pressure on the livestock producer to increase the productivity of rangelands. Range scientists, in some cases, concede that it is unwise to continually confront natural ecosystem forces by attempting to remove Gambel oak over broad areas at a relatively high cost while ignoring the renewable forage resource supplied by the oakbrush. Perhaps it is time for researchers and managers also to consider the possible worth of Gambel oak and concentrate more on developing its benefits to ranchers and society in general. The time may be approaching when range scientists and ranchers can no longer afford, economically and politically, to continue viewing Gambel oak only as a noxious species. Site specific manipulation of oak will continue to be important, but we will probably be unable to eradicate the species.

Growth and Morphology of Gambel Oak

Preformed shoots are characteristic of predeterminate species such as Gambel oak (Sweeney 1975, Dahl and Hyder 1977). These species have winter buds that contain a telescoped, fully formed shoot containing primordia of all leaves that will subsequently expand the following season. This 2-year process involves bud formation in the first year and elongation of the preformed components into a shoot the second year. Only a portion of the winter buds become active whereas others remain dormant. If new shoots are defoliated, for example, by early spring frost, other shoots often develop from dormant buds, depending on the degree of defoliation (Kozlowski 1971).

Gambel oak generally produces two kinds of shoots, i.e., long and short. Long shoots have leaves separated by distinct internodes and bear lateral buds which may develop either into more long shoots or short shoots (Kozlowski 1971, Dahl and Hyder 1977). Gambel oak sprouts are predominantly long shoots, and are more difficult to control than mature oak which have predominantly short shoots (Engle 1978). This characteristic of sprouts accounts for most difficulties encountered in herbicide control. That is, Wilson et al. (1975) suggested that for best control with herbicides, woody plants should have a higher proportion of short shoots. Carbohydrates and translocatable herbicides are moved mostly to the growing young leaves at the tip of long shoots instead of to the roots and other storage tissues. Long shoots are more prevalent in young trees than in older trees, and by the fourth or fifth order of branching, the long shoots bear only short shoots perhaps because of a general decrease in vigor (Wilson 1970). Therefore, young plants with larger proportions of long shoots are more difficult to kill with translocated herbicides than older plants (Dahl and Hyder 1977).

Oak trees ordinarily exhibit the intermittent type of growth common to most trees of temperate zones where height growth occurs in a single flush of growth (Zimmerman and Brown 1971). All the leaf primordia are preformed in the overwintering terminal bud and height growth is usually restricted to a single period early in the growing season.

The length of shoot elongation also affects the species' response to defoliation and herbicide applications. Mature Gambel oak have been reported to have a short period (24 to 27 days) of shoot growth, which is completed by the first week in July (Sweeney 1975), but Gambel oak sprouts have prolonged and numerous elongation periods (Engle and Bonham 1980). The duration of elongation in mature oak remains rather constant each year (Sweeney 1975). Gambel oak sprouts probably have a longer period of shoot elongation than do mature trees. Species of *Quercus* have a tendency to form "lammas shoots," which presumably appear around Lammas Day or August 1 (Kozlowski 1971). This type of shoot results from bursting and elongation of a current-year terminal bud on the main shoot or branch. Marquiss (1969) reported a late summer regrowth of Gambel oak in late August. Lammas

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shoots in *Quercus* are apparently longer than the early shoots of the first flush (Wight 1930). However, multiple flushes of growth have been reported in sprouts of two oak species (Boó and Pettit 1975, Engle and Bonham 1980). Dahl and Hyder (1977) were unable to explain the type of shoot growth pattern in the shoots of root suckers and stem sprouts resulting from various disturbances, but explained that since they usually continue to produce new foliage leaves and internodes throughout the growing season, they seem to fit the continuous growth pattern. This type of shoot extension occurs where maturation of the preformed telescoped shoot may be followed immediately by further extension growth including both the initiation and development of new or late leaves. Since these are long shoots, growth regulating herbicides are reduced in their effectiveness (Dahl and Hyder 1977). The combination of an erratic or continuous growth pattern and a predominance of long shoots at least partly explains the poor root kills of Gambel oak sprouts with application of growth-regulating herbicides.

The Root System of Gambel Oak

It appears that entire oak clumps are interconnected and are the product, through clonal development, of a single acorn (Muller 1951, Cottam et al. 1959). Van Epps (1974) believed clumps 24 m (80 ft.) apart were connected by their extensive root systems since it appeared that certain herbicides were translocated from treated to untreated clumps.

The survival ability of Gambel oak, like many other brush species, lies in its extensive root system. The root system of Gambel oak has been described as widespreading and freely branched, consisting of a shallow network of root-like structures which are largely rhizomes with only a few short feeding rootlets coupled to a system of deep-feeding roots (Baker and Korstian 1931, Christensen 1949, Muller 1951). These rhizomes allow an increased longevity of the individual plant and the multiplication of individuals under conditions which are too severe for seedling establishment (Muller 1951, Grover et al. 1970). Root: shoot ratios are very large. In fact, 90% of total biomass is below ground in sand shinnery oak *(Quercus havardii)*, a closely related sprouting oakbrush (Pettit and Deering 1971). This is likely to be a characteristic of Gambel oak sprouts that have had the mature top portions previously killed or removed. Thus, the potential for survival is tremendous. For example, leaf defoliation by goats of 90 to 95% at least 2 times per year for several years is necessary to obtain a high degree of control (near 95%) (Davis et al. 1975).

Successional Status of Oak Communities

We think that the conversion of oak chaparral or oak woodland to grassland is in opposition to the force of natural succession and results in a man-imposed disclimax. The wooded vegetation is likely the higher seral form although a subclimax in some cases and a climax in others. It has been suggested that the species forms a secondary successional stage in southern and southwestern Colorado where it has replaced ponderosa pine *(Pinus ponderosa)* and Douglas fir *(Pseudotsuga menziesii)* stands which have been removed by fire or logging (Brown 1958, Harrington 1964). Oakbrush has also been considered a climax type in southwestern Colorado where competing species are precluded due to edaphic or topographic conditions (Sweeney 1975). In Utah, Gambel oak has been considered the climax type (Baker and Korstian 1931, Hayward 1948, McKell 1950) and also a type successionally transitional to conifers (Dixon 1935, Lull and Ellison 1950).

Gambel oak's response to fire is typical of sprouting shrubs that dominate most natural shrublands. An open grassland, whether a disclimax or subclimax, will not result from a single fire episode. Although fire may top-kill Gambel oak, it usually stimulates sprouting, which in turn results in thickening open stands and merging of scattered stands into continuous thickets (Brown 1958). Fire may also initiate a Gambel oak stage of the pine forest sere by removing the competing pine overstory (Dick-Peddie and Moir 1970).

Whatever successional terminology is chosen to describe Gambel oak communities, one has to acknowledge that such stands are now a persistent component of foothill ecosystems of the southern Rocky Mountains. We submit that grass-dominated systems, other than the interspaces between oak motts, are a lower sere, definitely not a climax, and on most of the area will not persist in the absence of recurrent oak control efforts by man.

Carbohydrate Reserve Storage and Depletion in Gambel Oak

Poor root kills of Gambel oak, and especially of Gambel oak sprouts, have often been the result of poor timing of herbicide applications in relation to the pattern of depletion and storage of plant food reserves. This has often resulted in higher than normal root and crown sprouting, while producing adequate canopy destruction. Kozlowski and Keller (1966) described the pattern of carbohydrate translocation in temperate zone woody plants that have shoots preformed in the winter bud. The rapid burst of growth in internode expansion is usually completed before the leaves are fully grown and depends largely on stored carbohydrate reserves. Young leaves that have not completed growth do not readily export large amounts of assimilates to other plant parts. In this case, excess photosynthate is translocated to storage sites only after leaf maturation. Mature Gambel oak trees do not begin replenishing carbohydrate reserves until after full leaf size is reached (Marquiss 1969). However, leaves of expanding shoots or seedlings of woody plants generally begin exporting photosynthates to storage sites when the leaves reach 30 to 50% of full size (Zimmerman and Brown 1971). Boó and Pettit (1975) found that carbohydrates begin accumulating in the roots of sand shinnery oak when the leaves were one-third to one-half full size. Gambel oak sprouts also apparently begin storage in roots before leaves are fully expanded (Engle and Bonham 1980).

A single defoliation, by any method, is known to be most tive in accomplishing woody plant kills when plants are defoliated at the lowest point in the carbohydrate storage cycle (Cook 1966, Berg and Plumb 1972). Ordinarily, sprout vigor is lowest if shrubs are defoliated when carbohydrate reserves are lowest near the end of the spring flush of growth (Berg and Plumb 1972). Defoliation at this time reduces carbohydrate reserves by causing the plant to draw on already critically low reserves to produce new photosynthetic tissue, which in effect "starves" the plant. However, improper timing of herbicides and the resultant defoliations at higher points in the reserve cycle in Gambel oak sprouts may even increase root reserve levels, thus stimulating sprouting potential (Engle and Bonham 1980).

Sprouts of Gambel oak begin accumulating reserves before the leaves are fully expanded in the spring and a second period of rapid depletion occurs coincident with a vegetative regrowth period in the late summer (Engle and Bonham 1980). Mature Gambel oak trees exhibit an important difference in that there is only one period of depletion during the spring growth period, with the low point occurring when leaves are fully expanded (Marquiss 1969).

Leaf expansion is often used as a guideline for systemic herbicide applications because of the relationship of leaf expansion to net downward translocation of photosynthate. A properly timed herbicide application will intercept downward assimilate translocation so that maximum herbicide concentration will occur in the underground organs and damage to the plant will result there (Muzik 1970). Boó and Pettit (1975) noted that it is often assumed that herbicides should not be applied until leaves are fully expanded to obtain downward translocation in many undesireable shrub species. This is a valid recommendation for mature Gambel oak (Marquiss 1969) since these plants begin to store carbohydrates rapidly at this time and better movement of herbicides to the roots also occurs at this time. Boó and Pettit (1975) also observed that the previously recommended time for herbicide application for sand shinnery oak was when leaves were fully expanded. However, their data suggested that roots begin accumulating carbohydrates when leaves were only one-third to one-half full size. Maximum downward translocation of systemic herbicides might also be accomplished at this time. Likewise, herbicide applications to Gambel oak sprouts should also be made before full leaf stage is reached (Engle and Bonham 1980).

Methods of Gambel Oak Control

Effective Initial Plant Kills

Control efforts to date have emphasized only short-term control and few, if any, studies have been concerned with long-term control. It has been recognized that to minimize sprouting and to realize sustained forage production benefits, even on a short-term basis, high initial root kills of mature oak stands must be attained (Marquiss 1972). Chaining, a popular method of top removal, and other mechanical treatments, although economical on a short-term basis (Bartel and Sims 1978), have been unsatisfactory because of the prolific sprouting that follows treatment. Resulting thickets in just a few years may render these ranges less desirable for livestock production than ranges with original mature oak stands. High initial root kills of mature stands can be obtained, although probably not economically (Bartel and Sims 1978), by proper timing (at full leaf stage) of growth-regulating herbicides. Picloram (4-amino-3,5,6-trichloropicolinic acid) does offer consistently better, although still incomplete, root kills than other herbicides either applied alone or in mixtures (Marquiss 1973, Vallentine and Schwendiman 1973). On the other hand, intensive mechanical methods may or may not be effective on deep soils (Vallentine and Schwendiman 1973). Since existing methods appear to eventually result in serious sprouting problems, methods are still needed that will provide proven long-term control.

Maintenance Control

One must realize that using currently available methods to control or remove Gambel oak that is less than complete soil sterilization or conversion to introduced pasture will ultimately allow a sprouting problem. Conventional herbicide applications are ineffective in controlling oak sprouts (Bartel and Rittenhouse 1979). These authors have also suggested the use of some promising herbicides in a low-rate multiple application control program. Herbicides repeatedly applied in this fashion during periods of root reserve recharge may accomplish greater root kills, reduce available food reserves for regrowth, and ultimately reduce root:shoot ratios to a critical level for plant survival (Engle and Bonham 1980).

Biological control of sprouts with repeated browsing by goats has proven to be an effective means of near elimination of oak sprouts (Davis et al. 1975). However, their use is impractical in most situations because of problems in fencing and herding. Also, social bias has prevented the development of a market for goats.

Conclusions

Since Gambel oak is either a persistent subclimax to conifers or a climax species on foothill ranges, an open grassland created with oak control methods results in a lower seral stage. Thus Gambel oak will continue to return and dominate these ranges in the absence of recurrent control efforts by man. Additionally, the sprouting ability of Gambel oak inevitably results in sprout thickets which are even more difficult to control by any economical method.

Past failures associated with direct, high-cost environmental control of Gambel oak indicate that there continues to exist a critical need for research in the management and control of Gambel oak. Initial and, particularly, maintenance control methods are desperately needed that will be economically feasible on a long-term basis. To insure future success, researchers and managers should consider the ecological characteristics of Gambel oak when examining alternatives for controlling the species.

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