The Role of Shrubs in Diversifying a Crested Wheatgrass Monoculture

Cyrus M. McKell

ABSTRACT: Vegetation diversity and productivity of western rangelands have been reduced by selective grazing. Range improvement research in the late 1930's and 1940's suggested that controlling shrubs and seeding crested wheatgrass was a suitable answer to restoring range productivity. However, range ecosystems that resulted from widespread seeding with crested wheatgrass lack diversity in many important aspects. This paper discusses the nature of diversity and the role of shrubs in relation to the effective use of common-pool resources in range ecosystems. Shrubs can fill an ecological need in diversifying monocultures of crested wheatgrass and thus increase the spectrum of opportunity for multiple use management of public rangelands. Suitable methods for establishment and availability of seeds now make it possible to utilize superior species of shrubs in range improvement and land reclamation programs.

INTRODUCTION

Suggesting that shrubs can be used to diversify a crested wheatgrass monoculture may seem to be a great step backwards to those who consider shrubs undesirable and their control to be the first step in range improvement. However, shrubs possess many valuable characteristics useful to the productivity and stability of a rangeland ecosystem and have been described as an overlooked resource of arid lands (McKell 1975). Many shrub species, under appropriate management, can be useful components of rangeland vegetation, especially as an interplanting with crested wheatgrass (Agropyron desertorum (Fisch. ex Link) Schult.).

The purpose of this paper is to briefly look at the diversity problem in crested wheatgrass monocultures, review the nature of community diversity, examine how shrubs can contribute to grassland community stability, suggest how shrubs can enhance rangelands for multiple uses and finally, to describe ways of establishing shrubs in an existing crested wheatgrass stand.

Cyrus M. McKell is Vice President, Research, Plant Resources Institute, NPI, Salt Lake City, Utah.

THE DIVERSITY PROBLEM IN CRESTED WHEATGRASS PLANTINGS

Before discussing the role of shrubs in diversifying a crested wheatgrass monoculture, I believe it would be helpful to provide a brief historical perspective to the vegetation diversity question. In the 1930's there was widespread recognition that because of intense and unregulated grazing, the western rangelands were in a deteriorated condition and getting worse. Observers at that time reasoned that overgrazing had caused sagebrush (Artemisia tridentata Nutt.) and other shrubs to invade the depleted grasslands (Cottam and Stewart 1940). Later, Ellison (1960) showed that the vegetation diversity of sagebrush-bunchgrass range had been lost through livestock grazing that selectively reduced the grasses and palatable forbs, leaving sagebrush as the dominant. This conclusion has been validated by several studies in the sagebrush region (Eggler 1941, Vale 1975, Tisdale and Hironaka 1981). These studies have established that the sagebrush-grass region is ecologically stable and that sagebrush is an integral part of the regional climax vegetation.

Remedial action appeared to be necessary in the late 1930's and 1940's as mountain ranges serving a dual purpose as watersheds and grazing lands failed to hold intense summer rains and rapid spring runoff. The result was mud and rock flows into small communities along the Wasatch Front and other mountain west towns. The report of the Secretary of Agriculture to the U. S. Senate (1936) called for research "to develop low cost methods and suitable species for 'seeding or transplanting' on 38 million acres of rangelands now so badly depleted that reasonably rapid natural revegetation appears improbable." Research efforts to find appropriate species and methods for range improvement resulted in the highly successful formula of brush control and drill-seeding with crested wheatgrass. As early as the mid-1930's, crested wheatgrass was suggested as a possible choice for seeding rangelands drier than the Wasatch Plateau, location of the Great Basin Experiment Station (Keck 1972).

Brush control, vegetation type conversions, range improvement projects and watershed protection projects sponsored by the U. S. Forest Service and the Bureau of Land Management resulted in over 4 million acres (1,600,000 ha) of foothill and desert rangeland in the 10-16 inch rainfall zone being seeded to crested wheatgrass as a principal species (Valentine et al. 1963, Robertson 1947). In some locations other Agropyron species were seeded because they were better suited for site conditions (Plummer et al. 1968). Mixtures of a few species or single-species stands were observed to be easier to manage under grazing use than diverse, multiple-species stands (Cook 1966).

Reinvasion of sagebrush and other shrubs into a crested wheatgrass seeding may be a function of its relative openness (Cook and Lewis 1963, Rittenhouse and Sneva 1976). Blaisdell (1949) observed that the degree of competition between sagebrush and crested wheatgrass seedlings depended largely on their relative ages. According to Frischknecht and Bleak (1957), new crested wheatgrass stands are more vulnerable to invasion of shrub seedlings than old ones. Goodwin (1956) observed sagebrush reinvasion by seed dispersal and seedling establishment from the perimeter of crested wheatgrass plantings on several seeding projects in the Great Basin. The greatest incidence of sagebrush seedlings was near the perimeter of the seeded area and in places where the crested wheatgrass stand was thin. Wasser (1982) noted that greater stand longevity occurred when species used in seeding were of similar palatability and phenology. He did not place shrub reinvasion in context with this observation, however.

Good management of seeded stands of crested wheatgrass to minimize sagebrush reinvasion is necessary to keep the stand intact long enough for grazing to pay for seeding costs. Hubbard (1956) in his work with Purshia tridentata seedlings concluded that wheatgrass is as severe a competitor as native vegetation. The gradual increase in sagebrush canopy cover is a prime factor in reducing stand productivity (Frischknecht 1963, Rittenhouse and Sneva 1976). From an evaluation of forty-eight study sites, Shown et al. (1969) concluded that the most stable seedings of crested wheatgrass are those located on sites where annual precipitation exceeded 10 inches (250 mm) and soils were medium in moisture holding capacity. Site unsuitability was a large factor in reinvasion by various species of sagebrush, rabbitbrush (Chrysothamnus), and halophytes.

Whether a closed community (Robertson and Pearse 1945) exists or not in a crested wheatgrass monoculture has an important bearing on its long term stability and longevity. Unless a stand of crested wheatgrass effectively utilizes all factors of the environment at its various phenological stages, it cannot be considered closed. Another way of stating the case is to say that the stand should have sufficient resistance to change to prevent gradual reinvasion by forbs and shrubs as well as to make optimum use of abiotic resources. An examination of the nature of community diversity would therefore help in understanding the concept as applied to a monoculture.

NATURE OF COMMUNITY DIVERSITY

According to Harper (1977), community diversity is derived from five sources:

1) Somatic polymorphism within the genotype of a species provides for different expressions of root, stem, leaf, and flower sizes and their display according to the space available. Plants in a monoculture tend to emphasize diversity within the same morphological features. West and Rea (1979) working in native sagebrush-grass communities observed that community stability is achieved more by plant plasticity than by shifts in age class distribution, although pulses of establishment occur in favorable years.

2) Age distribution grouping occurs in response to cyclic temporal periods of suitable conditions for germination and establishment. Early seedlings may have a greater opportunity for growth than later ones of the same or different species, although a few may be found in an even-aged stand. Distribution of ages within a stand may be one of the elements of diversity that permit or deny recovery after stress. In the case of a crested wheatgrass monoculture, age distribution exhibits very little diversity once full stand establishment has occurred because new seedlings are denied the opportunity for survival (Cook and Lewis 1963).

3) Genetic variants within a species provide plants that can respond to the range of conditions within sites as well as those found over a spectrum of geographic locations. Species with great genetic diversity may be expected to include genetic combinations capable of resisting stresses as well as those responding to favorable conditions in given habitats. Continued natural selection under such conditions leads to ecotype development. Crested wheatgrass is an example of a genetic complex possessing wide variability as well as extensive stress tolerance. Dewey (1983) pointed out that crested wheatgrass taxonomy is complicated because the species and subspecies can hybridize with each other. However, A. desertorum is always tetraploid (2n=28) and less variable than the diverse materials referred to as A. cristatum (L.) Gaertn. Even so, this diversity is not as wide as the sum of all plant diversities in a mixed community.

4) Diversity of microsites within the habitat is a non-plant function that is important to community diversity and provides an opportunity for a range of genetic and somatic variants to establish and persist. The safe-site concept described by Harper (1977) and elaborated for rangeland conditions by Eckert et al. (1978) is a recognition that micro-site variability provides an opportunity for seedling establishment. Once a crested wheatgrass stand is established, further seedling recruitment is very limited. Within a fully stocked stand (Hyder and Sneva 1956), most if not all safe sites have been taken or modified. Competition from mature plants is extreme during critical stress periods when growth of new seedlings is most critical.

5) Diversity of growth form, consisting of generic and family diversity in morphology and community composition, provides for a stratification of the vegetal cover as well as distribution of roots. With such diversity, many different plant

species can be accommodated in their use of light, nutrients, water, heat, etc. for optimum growth over the maximum seasonal periods of favorability. A crested wheatgrass monoculture lacks the height, distribution of leaves and roots, and phenological range that a mixed plant community of shrubs, forbs, and grasses can display. However, physiological efficiency and concentration of biomass productivity in a short favorable season help compensate for the deficiency in life-form diversity.

To cope with the above elements or sources of diversity, various species maintain their place (to avoid a losing battle of competition) by specializing. Inasmuch as the resources needed by plants are distributed in space as well as time, various specializations are possible for plants to compete or survive.

Several papers in this conference provide information about crested wheatgrass that help to evaluate its characteristics as a unique biological entity and as an excellent range forage plant. This information should be evaluated in relation to those elements discussed by Harper (1977) as ways in which a species or a group of species can attain a sufficient diversity to effectively use common-pool resources:

1) Diversity in relation to the use of different resources. Some species become specialized in their use of pool resources such as development of exclusive mycorrhizal relationships to increase phosphorus uptake. Call and McKell (1982) reported that differences in mycorrhizal inoculation response among various shrub species were an indication of their ability to colonize new sites. Many rangeland species vary in their requirements for soil nutrients, and as Harris and Wilson (1970) showed, an annual species such as *Taeniatherum caput-medusae* (L.) Nevski, with a high capacity to respond to nitrogen, can dominate a perennial species such as *Agropyron spicatum* (Pursh.) Scribn. and Smith. Field observations indicate that seedlings of the annual species grow considerably faster than the perennial seedlings. Shrubs show less response to nitrogen than grasses.

2) Use of lateral heterogeneity of microsites. The observation of clumped plant distribution in arid and semi-arid ecosystems suggests a favorability created by one species for others associated with it. Rumbaugh et al. (1981) reported that fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.) created a more favorable habitat for production of forage by crested wheatgrass than when the crested wheatgrass was grown alone. Garcia-Moya and McKell (1972) used the term "islands of fertility" to describe the more favorable soil nitrogen status under shrubs in a desert environment than in the open spaces between shrubs. Charley (1972) also noted this soil fertility phenomenon in his work in the Great Basin.

3) Use of vertical heterogenity of environments. The canopy of shrubs offers considerable protection for understory species that lack stature. Such protection may be against intense grazing or cold temperature but also carries with it the risks of competition for soil moisture and sunlight, and possibly production of allelopathic substances. Rumbaugh et al. (1981) described a favorable influence of the fourwing saltbush canopy on crested wheatgrass and concluded that a synergistic condition was created for the grass by the shrub.

4) Use of resources temporally. A group of species with diverse phenological schedules can make greater use of common pool resources than a monoculture which concentrates its demands for resources according to a single schedule. For example, Fernandez and Caldwell (1975) pointed out that considerable difference exists in the time that maximum demands are made by the root systems of the three main subspecies of *Artemisia tridentata*. The continued root activity of these shrubs at a time when crested wheatgrass is dormant suggests that a stratification of activity exists which involves but minimal shrub-grass competition during fall months. Mohammad's (1979) work with responses of crested wheatgrass and fourwing saltbush to typical fall temperatures indicates a higher level of root activity of the shrub than the grass at a day-night alternating temperature of 11-7°C.

In each of the sources of community diversity described above, as well as the various ways that species use to survive in a diverse community, it seems clear that a monospecific community lacks sufficient diversity to achieve long-term stability or to exploit all environmental resources effectively. There is ample evidence that crested wheatgrass is well-adapted to many rangeland sites, especially those that were originally dominated by big sagebrush (Shown et al. 1969). Although crested wheatgrass has been a recommended choice for inclusion in rangeland seedings, extra management inputs may be necessary to make up for the diversity normally present in a multiple-species community. In some cases the usefulness of a crested wheatgrass monoculture may be less than that possible from a diverse community. The importance of shrubs to community diversity can be argued on the basis that they broaden the sources of productivity, increase opportunities for utilization, and extend ecological stability. Because community diversity is derived from various sources, each of these factors provide a degree of stability to the plant community. However, there is no satisfactory determinant of the amount of each diversity source needed to assure community stability or to allow additional species to enter the community.

NEED FOR DIVERSITY IN CRESTED WHEATGRASS STANDS

The need for diversity in crested wheatgrass seedings may not be perceived with equal understanding among range managers. The reason for this is their perception of the role shrubs play in the use of rangelands. If a range area is used principally for spring and summer grazing of livestock, a crested wheatgrass monoculture may be a suitable vegetal cover. However, a combination of grass and shrubs would be the best for wildlife habitat.

Even though management of rangelands is mandated to be on a multiple use basis (Public Land Law Review Commission 1970), some vegetation types may be more advantageously managed for a particular use than another because of the type of vegetation, topography, and other factors. The composition of the vegetation in a management unit is a big factor in determining optimum use(s). In general, a diverse vegetation composition is more amenable to multiple uses. Rumbaugh et al. (1981) concluded that combinations of shrubs and forbs with crested wheatgrass could extend the grazing season and provide a forage resource less susceptible to attacks by various insects and diseases than monocultures of crested wheatgrass.

Extensive areas seeded in the past to crested wheatgrass as a monoculture, or areas appropriate for a range improvement or reclamation project involving seeding, should be carefully considered in relation to the place that shrubs could fill in enhancing their future uses. The major uses of rangelands are grazing, wildlife, watershed, and recreation, and each has a particular requirement for shrubs.

SHRUBS INCREASE OPPORTUNITIES FOR MULTIPLE USE

Livestock Grazing

Five main feed criteria must be considered in evaluating species suitability for rangeland grazing. They are nutritional quality, palatability, digestibility, quantity, and seasonal availability.

Crested wheatgrass does an excellent job of meeting the first four conditions, but in the fifth criteria its nutritional quality is low in the post-maturity stage (Otsyina et al. 1982, Cook 1972). The best time for grazing use of crested wheatgrass is in the spring and early summer. Normally this is when livestock are in transition from winter grazing on the desert to summer grazing in the mountains.

Including shrubs as a protein source in crested wheatgrass monocultures has been suggested as a way to improve their use for fall and winter grazing (Monson 1980, Otsyina et al. 1982). Rumbaugh et al. (1981) reported the production of crude protein in August to be over ten times greater in plots containing fourwing saltbush and crested wheatgrass as compared with crested wheatgrass alone. In an October-November study grazing with fistulated sheep at the Nephi Field Station in central Utah, Otsyina (1983) found that diet of sheep on a grass/shrub pasture was adequate in digestible protein to sustain gestation while those on a grass alone pasture were deficient. The conclusion reached from these studies is that shrubs interplanted into crested wheatgrass monoculture plantings could provide adequate feed quality as well as extend the grazing season. Concern for the effect of grazing on regrowth of the shrub must be registered. Inasmuch as many shrubs are not fully dormant in the winter, intensive grazing must be approached carefully until further research is done. Observations of the shrubs following the grazing study at the Nephi Field Station indicated that shrubs are variable in their regrowth. In other studies spring and summer clipping appears to be more damaging than at any other season.

Wildlife Habitat

Because shrubs are used by wildlife for feed, escape cover, and thermal protection, they are a critical component of wildlife habitat. Each species of wildlife has its own set of habitat requirements (Institute for Land Rehabilitation 1978) for nourishment, survival, and reproduction. Wildlife habitat requirements often overlap as would be expected where many animal species are present. Thus, diversity is the main element of habitat quality to meet as many animal species needs as possible. Areas of sagebrush converted to crested wheatgrass can still be suitable sage grouse habitat if areas of sagebrush are left or if some brush reinvasion occurs. In an analysis of quality sage grouse habitat Phillips (1972) reported that sagebrush density of 2000 plants per acre was optimum for food and cover. Sagebrush stands of between 5 and 10 percent canopy cover afford the best conditions for growth of understory grasses and forbs. Deer habitat can be enhanced by open spaces seeded to crested wheatgrass as long as the openings are not any larger than 0.4 to 0.8 km wide (Institute for Land Rehabilitation 1978). Welch and McArthur (1979) identified several sagebrush accessions that meet protein requirements for winter deer feed. They pointed to the feasibility of using sagebrush and other shrubs for game range improvement. This follows earlier advice by Plummer et al. (1968).

Thus, shrubs are an essential part of most all wildlife habitats. Areas cleared of shrubby vegetation and seeded to crested wheatgrass should include selected shrub species in the seeding. If shrubs are not included in the seeding, eventually some shrubs will reinvade to provide diversity needed by wildlife.

Watershed

Adequate vegetal cover of the soil is one of the most critical aspects of a functioning watershed. Watershed condition can be measured in terms of minimal sediment yield and optimal water infiltration and yield. Loss of understory vegetation will increase soil erosion (Branson et al. 1973). Because deep percolation enhances watershed yield, any means to control shrubs might be construed as a means to increase waterflow. However, another force comes into play -- the overall stability of the soil mantle. Experience in 1983 and 1984 with accelerated spring runoff along the Wasatch Front of central Utah bears out the need for deep soil stability that is assisted by shrub roots permeating the saturated soil to the geologic parent material. A diverse cover of both deep rooted shrubs and relatively shallow-rooted grasses seems to be the best answer.

Surface Mining

Surface mining is only a temporary land use which by law (U. S. Congress 1977) must be ameliorated by replacement of spoil and topsoil, and seeding to a diverse and productive plant cover. Prevention of erosion and restoration of productivity are two key functions that justify reclamation costs that often range upwards to $2,500 per acre. Although regulations give priority to native species in the seeding mix, crested wheatgrass is frequently included with western wheatgrass (<u>Agropyron smithii</u> Rydb.), fourwing saltbush and sagebrush in seed mixtures (Hansen 1982). Stringent rules promulgated by the Office of Surface Mining require careful monitoring of species diversity to ensure that a broad spectrum of species and their attendant ecological stability results from seeding operations.

Recreational Use

Recreational use of rangelands includes many different activities as well as value judgements concerning environmental quality. How much a diverse vegetation adds to the recreation experience is not known. Questionnaires on attitudes tend to show that pristine-looking landscape rates higher in environmental quality than disturbed areas, and the greater the disturbance the lower the recreational experience. Whether shrubs growing in a seeded crested wheatgrass stand would raise the quality of experience of recreation visitors to the rangelands is doubtful, but if a shrub planting attracts a herd of antlered deer during the third week in October in Utah, there would be no question about a heightened recreational experience for a hunter with a loaded rifle!

WAYS TO ESTABLISH SHRUBS IN A RANGELAND SEEDED TO CRESTED WHEATGRASS

Inclusion of shrub seeds in a seeding mix is the best way to assure their presence in the resulting stand (Plummer et al. 1968). Large numbers of shrub seeds are being planted in the Intermountain West today as contrasted with ten years ago. Fourwing saltbush is especially favored as a species for seeding areas to be reclaimed from surface mining. Rangeland seedings for grazing are also now including palatable shrubs. Dependable seed supplies and improvement of techniques may be given credit for this.[1]

Shrubs seeded directly into existing crested wheatgrass stands face extreme odds for establishment (Hyder and Sneva 1956). The dense concentration of roots near the surface precludes shrub seedling root growth into moist soil. Van Epps and McKell (1977) reported success in shrub establishment by discing out three rows of crested wheatgrass and seeding in the open space thus created. No shrub seedlings were found in the space adjacent to the crested wheatgrass--thus indicating an area of high risk. Transplanting container-grown plantlets provides a means for establishing shrubs in an existing grass stand. Thousands of shrub seedlings were hand planted to diversify crested wheatgrass pastures at the Nephi Station in readiness for a grazing study (Otsyina 1983). This same technique has been used to establish shrubs in reclamation study sites in the Uinta basin of eastern Utah where rainfall averages below 7.0 inches (175 mm) (Institute for Land Rehabilitation 1979). Millions of container-grown shrubs have been transplanted to reclamation sites on a routine basis, thus providing assurance of the success available by following recommended procedures (Hansen 1982).

SUMMARY

By their very nature, crested wheatgrass monocultures lack diversity in many aspects. The uniformity obtained with this outstanding species overcomes some of the deficiencies that would otherwise occur with a species that is less vigorous, less productive and only moderately adapted to stress. The choice of crested wheatgrass for seeding western rangelands was indeed wise, but selected shrubs can help diversify the plant community to make it more stable, improve the use efficiency of environmental factors, and enhance the management of seeded rangelands for multiple uses. Establishment of shrubs by direct seeding or transplanting can be done with success.

[1]Roger Stewart. 1983. Personal communication from the Manager of NPI seed collections and seed processing facility, Ephriam, Utah.

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