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Problem Analysis for the Vegetation Diversity Project

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Technical Note

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PROBLEM ANALYSIS

FOR

THE VEGETATION DIVERSITY PROJECT

A Research and Demonstration Program to Restore and Maintain Native Plant Diversity on Deteriorated Rangelands of the Great Basin and Columbia Plateau

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Executive Summary

Management of the majority of public rangeland in the Great Basin and Columbia-Snake River Plateau falls under the authority of the Bureau of Land Management. The flora of this land ranges from highly diverse native plant communities to deteriorated lands dominated by exotic annuals. Approximately nine percent of the BLM's 78 million acres of public land in this region is degraded to such a degree that changes in land management alone will not result in significant improvement. The BLM intends to restore native plant communities on these deteriorated lands, but current revegetation techniques used to establish introduced perennial grasses are often unsuccessful in establishing native plants.

On lands where native communities exist, the BLM desires to maintain and to enhance native plant diversity. Encroachment of highly competitive exotic forbs and annual grasses in native plant communities raises concern among managers over the appropriate management to maintain native communities. Coupled with these concerns are impacts on vegetation of the documented increase in CO_2 and of predicted global climate change. The BLM therefore recognizes the need for research to understand and solve these problems and for the results of this research to be transferred to land managers.

The Great Basin and Columbia Plateau region consists of two major ecosystems: the sagebrush ecosystem, generally located in the northern half of the region; and the salt-desert shrub ecosystem, located in the southern half. These ecosystems differ greatly in their composition of plant species and in their climatic and soil conditions. Therefore, techniques developed in one ecosystem may not be directly transferred to the other ecosystem.

We propose to initially concentrate studies in the Wyoming big sagebrush communities of the sagebrush ecosystem, because: (1) these communities represent a large amount of the BLM lands in Oregon, Idaho, northeastern California, Nevada and Utah; and (2) the low precipitation within these communities limits the success of standard revegetation methods. Shadscale communities of the salt-desert shrub ecosystem were given the next priority for study. These communities are a major component in four of the five participating states. Since the shadscale communities differ greatly from sagebrush communities, studies of shadscale communities will be initiated when the project reaches full funding. Similar studies to those proposed here for sagebrush communities would be conducted on this new suite of species and environmental conditions. Low sagebrush communities would be given the lowest priority and are unlikely to be initiated. Plant associations in low sagebrush and Wyoming sagebrush communities are similar and thus promising techniques for the Wyoming sagebrush communities may work well in low sagebrush communities and may be attempted later in the project.

The studies fall under five major areas of investigation: (1) Long-term monitoring of vegetation diversity; (2) Competition and establishment; (3) Plant materials and seed technology; (4) Maintenance of desired native vegetation; and (5) Special status plants. Under each area of investigation a series of high, medium and low priority studies have been identified. The priorities will be used as a guide in preparing requests for proposals, and in selecting and funding studies through the duration of the project.

Funding levels will determine the number and scope of studies conducted. Under the initial funding level, only six to eight studies from among the high priority studies can be initiated.

Long-term monitoring plots would be established throughout the Great Basin to detect the effects of yearly variation in climate on the species composition, productivity, and structural diversity of plant communities with and without grazing. In conjunction with these plots, long-term studies would be conducted relating climatic variations and livestock use to the survival, reproduction, and seedling establishment of important native perennials.

Competition between exotic annuals and native perennials would be quantified and documented in controlled environments and in field studies. The role of elevated CO_2 levels and of precipitation shifts on the competitive relationship between desirable and undesirable plants should be examined.

Alternative methods to the standard rangeland drill technique would be examined for establishing species in wilderness areas or for establishing species that require intensive techniques for successful establishment.

The need for local seed sources to restore native vegetation should be examined in a study to compare the genetic variability with the environmental variability (phenotypic plasticity) within desirable native species. A high degree of genetic variability within a species would strongly suggest the need for collecting seeds of restoration species from nearby rather than distant populations.

Studies concerning the maintenance of desired native vegetation would examine the conditions required for exotic species to successfully invade and maintain populations in stands of diverse native vegetation.

Studies of special status plants will focus initially on collecting critical life history data (survival, seed production, seed bank persistence, germination and establishment) on species not restricted to specialized soil conditions and on species from similar genera or from similar growth forms.

Information gathered from these studies and from studies conducted by BLM district personnel will be transferred to land managers using a quarterly newsletter, demonstration sites, development or use of computer expert systems and through peer reviewed scientific journals.

Acknowledgments

Several individuals have contributed to the development of the Vegetation Diversity Project. We recognize the foresight of the three Oregon/Washington BLM District Offices, Burns, Spokane, and Vale, that initially identified a need for research on revegetation of semiarid rangelands using native species. We acknowledge the efforts of J. Asher in recognizing, organizing, and developing a multistate BLM research project plan. We acknowledge the efforts of other federal, state and university people who participated in workshops and committees and who made recommendations that were incorporated into this project.

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Introduction

The Great Basin and Columbia-Snake River Plateau are generally recognized as the geological boundaries of the Intermountain Region of the US. These lands are bounded by the Cascade and Sierra Nevada Mountains on the west and by the Rocky Mountains on the east and extend from the Canadian border in the north to the extremely arid environments of the Mohave and Sonoran Deserts of Nevada and Arizona. The vegetation supported by these lands is generally described as a shrub-steppe.

The Vegetation Diversity Project will target portions of the Great Basin and the Columbia-Snake River Plateau. Bureau of Land Management (BLM) managed lands within this target area include eastern Oregon, southern Idaho, western Utah, the northern two-thirds of Nevada, northeast California, and a small portion of California's Bishop Resource Area north of Owens Dry Lake.

Climatically, the region is characterized as semiarid with mean total precipitation ranging from 180 to 410 mm (7 to 16 in.). Most of the precipitation (70 to 80 %) comes during the winter as snow. Gradual snow melt allows infiltration of the moisture into the soil. The perennial plants that dominate the system utilize this moisture in the late-winter and spring for growth and reproduction.

Climatic shifts caused past vegetational shifts within this region. The periods of Pleistocene glaciation likely reduced summer temperatures and increased total precipitation resulting in conifer forests on the foothills and on valley bottoms that were not covered by lakes (Wells 1983). During warmer interglacial periods trees died while grasses and shrubs expanded back into the valleys and foothills. Less dramatic climatic and vegetational shifts were seen during the Holocene (Mehringer 1977, Thompson 1990).

Aboriginal humans may have caused vegetational changes by reducing browsing animals (Mehringer 1977) or through local overuse of areas (Samuels and Betancourt 1982), but larger changes can be traced to the last 150 years of occupancy by humans of European descent. European man began to settle this region during the mid-1800s. These early settlers intentionally and accidentally introduced plants from Europe and Asia (Mack 1986). Overgrazing by livestock occurred throughout the region from the late-1800s to the mid-1900s and led to a degradation of native vegetation on public rangelands over much of the region. The void left by the loss of native plants allowed introduced plants and less palatable native plants to rapidly expand and dominate many areas. Better grazing management has resulted in a reduction in grazing pressure and many improvements in vegetative composition and production of rangelands, but the loss of structural, functional, and species diversity within some of the native plant communities will require additional research to provide managers with sufficient information to facilitate recovery of deteriorated sites.

Management of the majority of public rangelands in the Great Basin and Columbia-Snake River Plateau falls under the authority of the BLM. Flora of BLM lands ranges from highly diverse native rangeland to deteriorated lands dominated by exotic annuals. For example, approximately nine percent of the BLM's 78 million acres of the public lands in this region are degraded to such a degree that changes in livestock management alone will not result in significant improvement. The BLM intends to restore native plant communities on selected areas that are currently deteriorated when native plant restoration is consistent with current land use plans. However, current revegetation techniques used to establish introduced perennial grasses have often been unsuccessful when attempting to restore native perennials. Where native communities exist, the BLM desires to maintain and enhance the diversity within these communities. However, encroachment of highly competitive exotic weeds into native plant communities raises a concern among managers over appropriate management to maintain native communities. Coupled with these concerns are impacts of the documented increase in CO, and of predicted global climate change on vegetation. The BLM therefore recognizes the need for research to understand and solve these problems and for technology transfer of research results to land managers to improve and maintain native plant diversity.

In preparing for this problem analysis, a workshop was convened (Krueger et al. 1989) to gain input from researchers and managers about current recommendations and research needs to accomplish the goal of restoring and maintaining diverse native plant communities in the Great Basin and Columbia-Snake River Plateau. After two BLM research scientists were hired, meetings were arranged between the scientists and participating BLM state offices (Idaho, Nevada, Oregon-Washington, Utah, and California), between the scientists and the five Oregon-Washington BLM district offices, and between the scientists and current research scientists in the Great Basin and Columbia-Snake River Plateau to provide additional input on needs for research.

In this problem analysis, we will review the literature and document on-going studies concerning diversity, restoration, and maintenance of native vegetation in the Great Basin and Columbia-Snake River Plateau. The review of the literature is not intended to be exhaustive but is intended to highlight some of the background information critical to this project. We will summarize the prioritized needs of the BLM managers. From this information base, we will prioritize the research and demonstration tasks that the project will address and we will discuss methods of transferring pertinent information to land managers for application in BLM districts in the Great Basin and Columbia-Snake River Plateau.

Literature Review and On-Going Studies

I. Ecosystem Descriptions

The Great Basin and Columbia Plateau region covers two major physiographic provinces: (1) the Columbia-Snake River Plateau Province in eastern Washington, Oregon, and southern Idaho; and (2) the Basin and Range Province in southcentral Oregon, northeastern California, Nevada, and western Utah (Hunt 1974) and incorporates four ecoregions with their associated vegetation (Omernik 1986, 1987): (1) Columbia Basin, (steppe and shrub-steppe); (2) Blue Mountains (mixed forest and shrub-steppe); (3) Snake River Basin/High Desert (sagebrush steppe); and (4) northern Basin and Range (sagebrush and salt-desert shrub)(Fig. 1). These two provinces differ in their underlying bedrock. The Columbia-Snake River Plateau was formed by lateral flows of basaltic lava during the Miocene and Pliocene. The loessal soil varies in depth depending on the time exposed to deposition and removal. The Basin and Range Province is characterized by a series of north-south tending valleys and fault-block mountain ranges. The soils are a combination of loessal, alluvial, or lacustrine fill. During the Pleistocene, lakes occupied many of the valleys in the Great Basin. Currently, these valleys are hydrologically closed basins lacking drainage to the sea and tending to have more alkaline soils than the Columbia-Snake River Plateau.

Vegetation types found in the Intermountain West range from steppe to shrub-steppe to xeric woodlands. For purposes of narrowing the focus of this project, juniper woodland sites will not be considered. Although there are many problems requiring research in juniper ecosystems, such as the encroachment of juniper into formerly sagebrush dominated sites and the effects on watershed stability of juniper dominance, this project will concentrate on problems of shrub-steppe communities. Kuchler (1970) describes six zonal potential natural vegetation systems for the Great Basin and Columbia Plateau. We will use these described ecosystems as a general overview.

Two steppe ecosystems are found on the Palouse Prairie of Washington and Oregon. The fescue-wheatgrass *(Festuca-Agropyon)* type is restricted to the mesic, deep soil sites of eastern Washington. The wheatgrass-bluegrass *(Agropyron-Poa)* type occurs on shallower soils than the fescue-wheatgrass type and is found in southeastern Washington and in a narrow band in northeastern Oregon (West 1988). Lands within these ecosystems tend to be privately owned and will not be discussed further in this analysis.

Two sagebrush ecosystems dominate the majority of the region. The sagebrush steppe (woody *Artemisia)* is the largest ecosystem covering nearly 45 million ha including portions of southcentral Washington, most of eastern Oregon, southern Idaho, northern California, and the northern edges of Nevada and Utah. The majority of the ecosystem lies within the Columbia-Snake River Plateau, although it extends into the northern portion of the Basin and Range Province. The Great Basin sagebrush ecosystem occupies most of eastern Nevada and occurs throughout central and southern Utah. West (1983a) indicates that these two ecosystems are closely related and are largely separated because the more arid Great Basin sagebrush ecosystem is less likely to recover following disturbances than the sagebrush steppe.

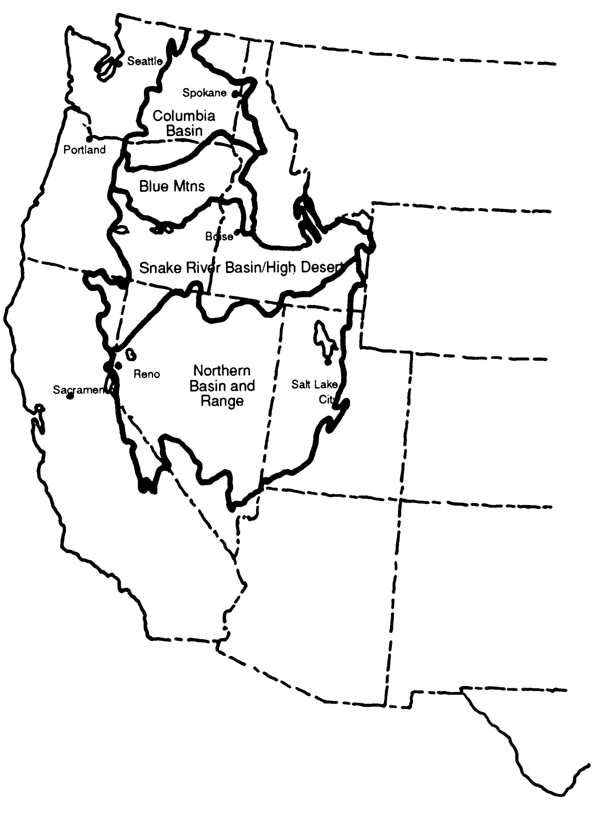

Figure 1. Map depicting the location of the four ecoregions of the western United States that outline the study area for the Vegetation Diversity Project. The Columbia Basin, Blue Mountains, and the northern half of the Snake River Basin/High Desert ecoregions lie within the Columbia-Snake River Plateau physiographic province. The Basin and Range, and the southern half of the Snake River Basin/High Desert ecoregions lie within the Basin and Range physiographic province (Hunt 1974, Omernik 1986).

The last major ecosystem within the region is the salt-desert shrubland. This ecosystem is dominated by shrubs and half-shrubs of the Chenopodiaceae such as shadscale *(Atriplex confertifolia)* and winterfat (*Ceratoides lanata*). Although the ecosystem's name would indicate saline soils, this is not the rule for the entire ecosystem. Chenopod shrubs dominate non-saline soils in arid regions of Nevada east of the Sierra-Nevada Mountains (Billings 1949). Physiographically, this ecosystem is largely restricted to the Basin and Range Province with two-thirds of its area found in Nevada and Utah (West 1983b).

Most of the BLM lands in the Great Basin and Columbia Plateau lie within the two sagebrush ecosystems and the salt-desert shrubland ecosystem. We will describe in more detail below the important plant, animal and microbial components of these ecosystems.

A. Sagebrush Ecosystems

The sagebrush ecosystem is the highest priority system for BLM lands of the Great Basin and Columbia Plateau because of the extent of coverage and because of the identified management concern within most State BLM offices (see Concerns of Land and Resource Managers). Although big sagebrush *(Artemisia tridentata)* is the dominant shrub in plant associations, three subspecies may occur depending on the soils, available moisture, and soil temperature (elevation). Wyoming big sagebrush *(A. t. wyomingensis)* grows on arid, warm soils on lowland sites. Mountain big sagebrush *(A. t. vaseyana)* grows on mesic, cool soils at higher elevations, whereas basin big sagebrush *(A. t. tridentata)* is found on sites with intermediate characteristics (West 1979, Hironaka et al. 1983, Winward 1983) or on deep soils or on soils with enhanced water availability (J.E. Anderson, pers. comm.). Regardless of the subspecies, descriptions are similar of big sagebrush in relatively undisturbed communities. Canopy coverage averages 15% (range 4 to 25%) for *A.t. wyomingensis* and *A.t. tridentata* and 20% for *A.t.* vaseyana with sagebrush composing about 10% (range 4 to 20%) of the total vegetation cover or biomass (Hall 1973, Mason 1978, Bunting et al. 1987).

The herbaceous component of these communities is dominated by perennial bunchgrasses such as bluebunch wheatgrass *(Pseudoroegneria spicata* formerly *Agropyron spicatum),* Sandberg's bluegrass *(Poa sandbergii),* and Idaho fescue *(Festuca idahoensis).* Other grasses that are often less prominent in less disturbed communities are squirreltail *(Sitanion hystrix),* needle-and-thread *(Stipa comata),* and Thurber's needlegrass *(Stipa thurberiana).* Idaho fescue occurs on the more mesic sagebrush sites, whereas bluebunch wheatgrass is common to all of the sites (Franklin and Dyrness *1973). Stipa* spp. become more abundant further south in the region (Nevada and Utah). On sandy soils, Indian ricegrass *(Oryzopsis hymenoides)* may occur in association with sagebrush and bluebunch wheatgrass.

The perennial forb component of the sagebrush steppe is represented by a wide variety of species. In eastern Washington, canopy coverage for perennial forbs averages 7% and contributes about 4% of the total plant coverage (Daubenmire 1970). Some common species in this community are long-leaved phlox *(Phlox longifolia),* hooker's onion *(Allium acuminatum),* and shaggy fleabane *(Erigeron pumilus).*

Those areas of the soil surface not covered by vascular plants are often covered by a fragile cryptogamic crust of lichens and mosses. Daubenmire (1970) provides a list of 15 genera of lichens and mosses identified in pristine sagebrush communities in eastern Washington. Repeated soil disturbance leads to a reduction in the crust.

Dwarf sagebrush species *(Artemisia arbuscula, A. longiloba,* and *A. nova)* replace big sagebrush as the dominant shrub on shallow soils within this ecosystem in southern Oregon, northern Nevada, and southern Idaho. Soil characteristics appear to determine the dwarf sagebrush that will dominate the site. Either *A. arbuscula* or *A. longiloba* dominates sites with noncalcareous soils or with a dense clay horizon between 5 and 30 cm below the soil surface. In contrast, *A. nova* is found on sites with calcareous soils in Nevada (Zamora and Tueller 1973), but is located on shallow soils overlying basalt flows in Idaho (J.E. Anderson, pers. comm.).

The dominant grasses and forbs of dwarf sagebrush communities are similar to those found in the big sagebrush communities. Coverage of Idaho fescue and bluebunch wheatgrass are less than their equivalent big sagebrush counterparts, whereas Sandberg's bluegrass is slightly higher in coverage (Culver 1964).

Loss of one or several components of the structural diversity (e.g., shrubs, forbs, or grasses) is a major concern to managers (see Concerns of Land and Resource Managers below). Techniques for the reintroduction of these components without eliminating the intact components are desired. Severe disturbances often encourage the spread and dominance of exotic weedy species.

These exotic species, such as cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusae*), are often represented in relatively undisturbed communities, but tend to remain as subordinate species (approx. 5% or less canopy coverage). With disturbance, these grazing-tolerant or grazing-avoiding competitive species can quickly expand and dominate sites. The role of climate (e.g. shifts between drought and favorable moisture conditions) in dictating potential expansion of these species is not well understood. Concern has been expressed by James A. Young (USDA-ARS, Reno, personal communication) over the potential surge in medusahead dominance once the current region-wide drought ends.

Overgrazing and frequent wildfires have led to the dominance of cheatgrass on over 40 million ha (99 million ac) in the Intermountain West (Mack 1981). On some sites in northeastern California and northwestern Nevada, plant dominance has shifted from cheatgrass to medusahead and later to one of the knapweeds, yellow starthistle *(Centaurea solstitia/is)* (pers. comm. J.A. Young). Research is needed to identify native species which can be established as a single species or as combinations which are competitive with these exotic weeds. We also need to understand how livestock utilization of natives may affect the exotic species.

Woody vegetation within this ecosystem tends to create areas of greater nutrient concentrations, 'islands of fertility' (see review by West 1991). Woody plants remove nutrients from surrounding interspaces and distribute it in the form of litter beneath their canopies. Shrubs also provide structural diversity within communities which enhances the capture of vesicular-arbuscular mycorrhizae (VAM) spores (Allen and MacMahon 1985) and of snow (Allen et al. 1987). As a consequence, microbial and animal activity associated with nutrient cycling is often concentrated in these patches.

VAM are associated with most dominant native perennials within arid and semiarid lands (Miller 1979, Trappe 1981) and may enhance nutrient and water uptake by plants (Harley and Smith 1983, Allen and Boosalis 1983). The presence of VAM in disturbed sagebrush ecosystems may enhance the restoration of native perennials by increasing the capacity of the perennials to capture resources when competing with nonmycorrhizal or facultatively mycorrhizal exotic annuals (Allen 1988). However, site preparation techniques that disturb the soil may reduce the likelihood of infection because these techniques destroy the mycelial network that formerly existed (Evans and Miller 1990).

Successful restoration may require creating artificial islands that simulate the structural and functional conditions that shrubs create in the ecosystem. This may require the use of structures such as snowfences and mulch to enhance the restoration of some natives.

B. Salt-Desert Shrub Ecosystems

The presence of dominant species throughout this ecosystem is largely dictated by soil salinity levels. Although presence of a species is not a useful indicator of soil salinity because of the wide range of tolerances among species (Gates et al. 1956), there is an accepted trend that as salinity increases across the landscape, plant associations tend to shift. This gradient of associations proceeds from lower to higher salinity as follows: (1) big sagebrush; (2) spiny hopsage (Grayia spinosa), rabbitbrush *(Chrysothamnus* spp.), horsebrush (*Tetradymia* spp.); (3) winterfat; (4) shadscale; (5) greasewood *(Sarcobatus vermiculatus),* red sage *(Kochia americana),* Nutall's saltbush *(Atriplex nuttallii); (6)* seablite *(Suaeda* spp.), saltgrass *(Distichlis stricta),* saltwort *(Salicornia* spp.), *Allenrolfea* spp. (Gates et al. 1956, Flowers and Evans 1966).

Descriptions of the plant associations within this ecosystem provide less detail than do descriptions of the sagebrush ecosystem. West (1983b) splits the ecosystem into two major subdivisions based on subsurface water within or remaining below the upper 1 m (3 ft) of the soil. Lowland habitats are typically found near the central playa of enclosed basins. The water table is occasionally present at the surface and remains within the upper 1 m (3 ft). Vegetation in this region is therefore dominated by those halophytes, such as greasewood *(Sarcobatus vermiculatus),* some low-growing half-shrubs *(Allenrolfea occidentalis* and *Salicornia utahensis),* and saltgrass *(Distichlis stricta),* that can tolerate occasional anaerobic conditions in the root zone . Descriptions of plant communities with some quantitative information are available for northern Utah (Fautin 1946, Flowers and Evans 1966). These communities are not a major problem for the BLM in the Great Basin and therefore are not included in the remaining discussion of the problem analysis.

Upland habitats are characterized by the water table remaining below a 1 m (3 ft) depth. Shadscale *(Atriplex confertifolia)* is the principal upland shrub and dominates upland habitats. Shadscale is a complex species consisting of several polyploid races. Diploid races are generally found in upland habitats at elevations above the upper levels of the Pleistocene lakes whereas polyploids are associated with valley bottoms throughout the Great Basin (Stutz and Sanderson 1983). After the recession of the Pleistocene lakes, shadscale appears to have expanded its range from two geographical regions: (1) from the lee side of the Sierra Nevada Range and (2) from the Colorado Plateau (Sanderson et al. 1990). As it expanded its range, distinct morphological and chemical differences evolved. In general, diploid populations are found on mesic sites whereas polyploid populations are associated with either drier or more alkaline sites (Sanderson et al. 1989).

Shadscale communities contain one or more associated species. Associated shrubs include winterfat, bud sage (*Artemisia spinescens*), spiny hopsage, and Mormon tea (*Ephedra nevadensis*). Canopy coverage averages from 0.5 to 2% with maximum values of 6% (Fautin 1946). The perennial herbaceous component is represented by grasses such as basin wildrye (*Elymus cinereus*), Indian ricegrass *(Oryzopsis hymenoides),* and squirreltail *(Sitanion hystrix)* in the northern portions of the Great Basin (Franklin and Dyrness 1973). Further south, summer precipitation occurs with greater regularity causing a shift to Indian ricegrass and galleta grass *(Hilaria jamesii)* (Fautin 4946, Billings 1951, West and Ibrahim 1968). Native forbs are a minor component in shadscale communities and are largely represented by globemallow *(Sphaeralcea* spp.) .

Winterfat communities occur throughout the Great Basin and appear as localized 'islands' within shadscale communities (Fautin 1946). Winter-fat communities differ from shadscale communities mainly because winterfat communities lack shadscale. Billings (1945) speculated that winterfat dominates in areas where shadscale has died, but additional support for this hypothesis does not exist.

Regardless of the specific vegetation association, plant coverage in upland communities averages about 7 to 8% with interspaces between plants occupied by mycrophytic crusts and rocks (Billings 1949, 1951, Fautin 1946, West and Ibrahim 1968, West 1983b). These crusts are composed of free-living, nitrogen-fixing bacteria, lichens and blue-green algae which enhance soil stability, improve water infiltration, provide pulses of available nitrogen, and enhance seedling establishment (Loope and Gifford 1972, Rychert and Skujins 1974, Kleiner and Harper 1977, St. Clair et al. 1984). Although chenopods are non-mycorrhizal plants (Allen 1988) these microphytic crusts appear to fill a niche similar to the niche VAM fills in sagebrush ecosystems.

Exotic weedy species are as much a component of this ecosystem as they are in the sagebrush ecosystem.

Cheatgrass has been noted as a component in the upland salt-desert shrub since before the 1940s (Fautin 1946). Some areas have experienced shifts from shadscale dominance to cheatgrass (Sparks et al. 1990). Although cheatgrass is present, it is not the fire risk in salt desert shrub communities that it is in shrub-steppe communities because it does not normally produce sufficient fuel to carry wildfires (West 1983b). Currently, medusahead and the knapweeds are not found on these sites, but their ranges may not have reached their maximum. Two chenopod annuals, Russian thistle (*Salsola* and halogeton (*Halogeton glomerata*), are found on sites of severe soil disturbance. These annuals were a major problem in Utah and Nevada with severe overgrazing before the 1950s. The reduction of livestock numbers and a shift in grazing season resulted in a decline in the impact of chenopod exotics (West 1983b).

It is relatively common for shrubs in this ecosystem to experience cycles of mortality (Nelson et al. 1989, Pyke and Dobrowolski 1989). Successful restoration of native plants within this ecosystem depends largely on adequate precipitation during germination and establishment. Natural reseeding via a residual seedbank may provide the greatest success. If seedbanks no longer exist, then technologies for successful restoration are limited (see papers in Tiedemann et al. 1983). Basic demographic research concerning reproduction, seedbanks, seed germination conditions and seedling survival conditions is needed for the dominant shrubs, forbs and grasses of this ecosystem. This research should also identify the impact of livestock and wildlife on these demographic parameters.

II. Vegetation Dynamics of Semiarid Communities

Forecasts of the likelihood that a site will successfully recover after a disturbance are based on models of vegetation dynamics for similar sites. Much of our current basis for judging rangeland dynamics is based on the theory that successional trajectory will lead to a single plant community provided that severe disturbances are eliminated. This single plant community is commonly called a climatic climax or a potential natural community. This view of rangeland condition is based on Clements' idea that communities pass through a succession of intermediate communities before attaining a stable community, the climatic climax. These ideas are widely taught and are presented in current textbooks of rangeland management (e.g., Stoddart et al. 1975, Heady 1975, Holechek et al. 1989). The traditional rangeland dynamics model used in determining condition classes in the United States were developed by Dyksterhuis (1949, 1958) became accepted by federal land management agencies in the late 1960s (e.g., USDA 1969) and were included in Stoddart, Smith and Boxs' (1975) range management text.

This successional approach for defining rangeland condition classes was strongly criticized because it did not accurately reflect the health of grazed rangeland. For example, the species composition of herbaceous plants in communities dominated by woody plants tends to decline in the understory as woody species dominate the site. As woody plants become dense the elimination of livestock grazing will not be sufficient to allow the herbaceous plants to recover. On some sites, woody plants replace herbaceous plants regardless of the livestock grazing because suppression of fires allows the more competitive woody species to dominate. Because of several problems associated with inaccurate condition classes formulated from the traditional rangeland succession model, the Rangeland Inventory Standardization Committee (1983) recommended using the potential natural community (PNC) concept of comparing the current vegetation to the potential community the site can accommodate while considering past modifications of the site. Under the PNC approach, managers recognize that a site may develop into one of many potential communities depending upon the type and severity of the disturbance on the site. Yet, the PNC approach largely recognizes a single steady state that the community will achieve if disturbances are eliminated. Intermediate stages are recognized as successional stages that develop from early-seral to mid-seral to late-seral communities after disturbances are eliminated or reduced. This approach is currently being used by several federal agencies including the BLM to describe rangeland condition.

Regardless of the traditional condition class approach chosen, both are strongly rooted in the Clementsian theory that succession is a predictable linear bi-directional process. Succession progresses towards a climax or potential community if disturbances are eliminated and regresses from the climax or potential community if disturbances continue. These two ideas have largely been accepted for rangeland management because of the desire to find a single objective standard for comparing the impacts of grazing animals on each vegetation community (Smith 1988).

Alternative theories of vegetation dynamics take an individual species approach to the development of communities based on the early work of Gleason (1926). These alternatives rely on the species' life-history and on the interactions among the individuals that constitute the population and between the individual and its environment (Connell and Slatyer 1977, White 1979, Noble and Slatyer 1980, Westoby 1980, Huston and Smith 1987, Westoby et al. 1989). Under these theories, disturbance becomes a part of the ecosystem and several stable communities have the potential to develop after disturbances are eliminated or reduced. The nature, frequency, and intensity of the disturbance differentially impact each plant species, therefore the community formed after a disturbance may depend on the abilities of the species to survive the disturbance or to replace themselves through reproduction after the disturbance. The likelihood of a species surviving or replacing itself after a disturbance depends on the species germination characteristics, competitive ability, growth, phenology, and on its genetic variability and plasticity related to the myriad of environmental factors it may face. In short, forecasting the dynamics of a community following a disturbance requires the knowledge of the physiological and demographic responses of the individuals that constitute the interacting populations of species that form that community.

The individualistic approach to vegetation dynamics recognizes that more than one potential community can result following a disturbance. Acceptance of this idea has led to the recognition that multiple stable states or communities may exist for any given site (Holling 1973, May 1977, Walker et al. 1981). In a recent review of rangeland successional models, Westoby et al. (1989) outlined the limitations and exceptions to the traditional approach that lead them to advocate that many stable plant communities have the potential to exist on any given landscape. They have proposed an alternative state-and-transition model for describing rangelands and for applying management prescriptions. States are relatively stable assemblages of species that develop on a site depending on the timing, intensity and severity of disturbances. Transitions, also referred to as thresholds (c.f., Friedel 1991), are actions that result in new states (communities) of species assemblages. Transitions are characterized by the following: (1) unpredictable natural events, such as fires or changing climatic conditions, or human-induced uses of the ecosystem, such as farming or grazing; and (2) the change in states is not reversible on a practicable management time scale without human intervention (e.g., artificial restoration).

We believe that the state-and-transition model is more appropriate for restoration and maintenance of semi-arid communities of the Great Basin and Columbia-Snake River Plateau. This approach has been successfully applied to arid and semiarid rangelands where the interaction between different types of disturbance and climate can lead to alternative stable plant communities. Within the Great Basin and Columbia-Snake River Plateaus, Laycock (1991) proposed a state-and-transition model for the sagebrush-steppe ecosystem that combines transitions resulting from grazing, fire, and climatic conditions that result in the development of six relatively stable communities (Fig. 2). Refinement of such a sagebrush-steppe model should be incorporated into some of the long-term monitoring of undisturbed and disturbed communities within the Great Basin and Columbia Plateau. Analysis of plant community data should incorporate ordination techniques to document when communities have transcended between vegetation

STATE-AND-TRANSITION MODEL FOR A SAGEBRUSH GRASS ECOSYSTEM
(After Westoby, Walker and Noy-Meir, 1989)

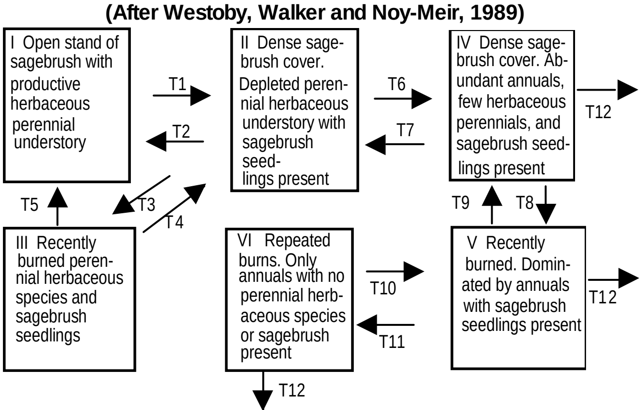

Figure 2. State-and-transition diagram for sagebrush-grass vegetation. An arrow represents the transition (T) between stable states.

Transitions between stable states in the absence of annuals as dominants:

T1 · Heavy continued grazing. Rainfall conducive for sagebrush seedlings.
T2 · Difficult threshold to cross. Transitions usually will go through T3 and T5.
T3 · Fire kills sagebrush. Biological agents such as insects, disease or continued heavy browsing of the sagebrush by ungulates could have the same effect over a longer period of time. Perennial herbaceous species regain vigor.
T4 · Uncontrolled heavy grazing favors sagebrush and reduces perennial herbaceous vigor.
T5 · Light grazing allows herbaceous perennials to compete with sagebrush and to increase.

If climate is favorable for annuals such as cheatgrass, the following transitions may occur:

T6 · Continued heavy grazing favors annual grasses which replace perennials.
T7 Difficult threshold to cross. Highly unlikely if annuals are adapted to area.
T8 · Burning removes adult sagebrush plants. Sagebrush in seed bank.
T9 · In absence of repeated fires, sagebrush seedlings mature and again dominate community.
T10 Repeated burns kill sagebrush seedlings and remove seed source.
T11 · Difficult threshold to cross if large areas affected. Requires sagebrush seed source.
T12 · Intervention by man in form of seeding of adapted perennials.

states and to determine when significant management efforts are required to return a community to a previous state (Friedel 1991). For salt-desert shrub ecosystems, similar models need to be developed to provide managers with a more accurate method of predicting the impact of disturbances on salt-desert shrub communities.

III. Competition and Establishment

A. Factors in Competition

According to Nowak and Anderson (manuscript in preparation), aboveground productivity of sagebrush-steppe vegetation in the Great Basin is thought to be limited first by water and then by nitrogen. They also state that the agents of stress in arid and semiarid ecosystems in western North America are likely to disrupt water and nutrient cycles with a resulting impact on plant interactions. Plant densities, relative competitive abilities, site adaptation, and proper seeding techniques must also be considered as factors contributing to plant interactions.

Water

Plant competition for soil water generally is extreme in arid regions. A dense stand of annual vegetation such as cheatgrass *(Bromus tectorum),* halogeton (*Halogeton glomeratus)* or Russian thistle (*Salsola kali)* may compete so intensely with seeded or transplanted perennial species as to inhibit their establishment or reduce their vigor sufficiently to limit survival and growth. Whenever surface disturbance occurs, the invasion of annual species is especially acute. Thus, any manipulation of the vegetation or soil surface that increases water accumulation and retention for beneficial use by specific desirable plants would be advantageous (Van Epps and McKell 1983).

Nutrient Levels

McLendon and Redente (1991) discussed the roles of nutrient availability and mineralization as external factors in dominance and succession on disturbed sites. Results of their study suggested that dominance of a site by annuals in early phases following soil disturbance is related to high nutrient availability. Several studies were cited to provide the following rationale: The higher potential growth rates of successional annuals might allow them to outperform the slower-growing perennials as long as resources are relatively abundant. However, as resources become more limiting, species with lower nutrient requirements (per unit biomass) should have the advantage. Dominance of disturbed nutrient-rich sites by annuals may be a function of two major factors: seed availability and rapid potential growth rate. The relatively high levels of available resources often characteristic of initial conditions in secondary succession allow the potentially high growth rate of early-successional annuals to be expressed. High growth rates under such conditions result in high biomass production, a rapid incorporation of nutrients, and a reduction in their corresponding levels in the available nutrient pool. If the decomposition rate lagged behind this uptake rate, a temporary deficiency would occur. Such a deficiency could reduce the growth of annuals sufficiently to allow for an increase in growth by less nutrient-demanding perennials. McLendon and Redente (1991) concluded that an ample supply of nitrogen (N) is the key factor in the ability of annuals to achieve and maintain dominance on recently disturbed sites, even in semiarid ecosystems. Their results suggested: 1) since important keys to understanding plant succession dynamics lie specifically in N availability, then, by implication, the processes of decomposition and mineralization appear to be important successional factors; and 2) general successional processes hold true for semiarid as well as for mesic systems.

The unpredictability of climate in the region results in some years when resources are high so that competitive plants are favored. However, in years when resources are limited, such as during droughts, plants that are stress tolerant are often favored (see review by Pyke and Archer 1991). Plants chosen for restoration need to combine characteristics of both competitiveness and stress tolerance.

Providing a mixture of species in a community is one approach to reducing the impact of unpredictable climatic events. Field experiments often indicate that multiple resources may limit plant growth (Lauenroth et al. 1978, Chapin and Shaver 1985). High diversity communities can maximize resource utilization not only across a heterogenous landscape, but also over time (McNaughton 1977, Chapin and Shaver 1985, Collins et al. 1987).

Plant Density

Intensity and effects of competition are accentuated at higher plant densities. Excessive seeding rates may have no significant benefit on total stand productivity, but may produce a density-induced reduction in individual plant biomass. Innate competitive ability is influenced by density effects. Samuel and DePuit (1987) reported that perennial grasses responded differently in competition. Species with higher innate competitive ability increased in abundance in response to seeding rate. Species with lower inherent competitive ability were eventually retarded by more responsive species as seeding rates and hence plant densities increased. This density-dependent increase in competitive exclusion was reflected in the decline of seeded grass diversity as seeding rates increased. Overly heavy seeding rates should be avoided in situations where mixed stands are desired.

Another approach to reducing negative effects of high density on establishment involves increasing the distance between a plant and its nearest competitor. Removal of competing vegetation can be accomplished by mechanical means, herbicides, prescribed burning, grazing, etc. Proximity of competing species may be reduced by planting seeds of different species into different microsites, rows, etc.

Relative Competitive Abilities

Innate differences in competitive ability among species may strongly influence competitive interactions and, therefore, establishment among species in mixtures. Relative competitive abilities of plants may be related to seed size, relative ease and rapidity of germination, seedling vigor, production potential, and/or site (environmental) adaptation. Competitive ability among species should be considered when mixtures of seeded species are composed. Seed mixtures that contain competitively superior species often produce stands in which composition is not related to the seed composition (DePuit and Coenenberg 1979, Schuman et al. 1982, Redente et al. 1984). Consideration should also be given to nonseeded species which may potentially be important competitors. Properly applied seeding methods and other cultural practices may sometimes compensate for interspecific differences when attempting to establish species with differing competitive and/or germination attributes. Seeding less competitive species first, allowing sufficient time for establishment, and later interseeding more competitive species may be a method of overcoming differences in seedling vigor (Coenenberg 1982).

Competitive abilities can be quantified using species mixture experiments similar to those presented by Law and Watkinson (1987). These experiments should be conducted at field locations so that density-dependent and density-independent effects could be determined.

Steve Monsen (personal communication) has observed that attempting to transplant native shrub seedlings into established crested wheatgrass has often failed. Transplanting native shrub seedlings into stands of established native grasses may have a better chance of success because native grasses generally have coexisted with native shrubs and are thus less competitive with them.

Harris (1977) discussed root phenology as a factor of competition among grass seedlings. He compared root phenology characteristics of cheatgrass, medusahead and bluebunch wheatgrass seedlings. Root phenology characteristics of cheatgrass and medusahead seedlings enable them to out-compete seedlings of bluebunch wheatgrass. Seeds of annual grasses germinate earlier in the fall, under drier and colder conditions than do bluebunch wheatgrass. Once germinated, roots of the annuals grow faster, not only under conditions of favorable fall temperature and moisture, but at near-freezing soil temperatures typical of winter in the northwest which includes the northern Great Basin and Columbia Plateau regions. The annuals also increase their number and length of roots during winter so that by spring they are in control of the site. Annual grasses exhaust upper profile available moisture supplies to depths beyond the reach of developing bluebunch wheatgrass roots. Consequently, bluebunch wheatgrass seedlings succumb to drought, under these conditions, before producing seeds. The annuals also die, but not before reproduction. If a bluebunch wheatgrass seedling does survive the summer, its root phenology pattern changes to include a period of summer dormancy, which provides a competitive advantage over annuals. Successful establishment of bluebunch wheatgrass requires control of annuals.

Harris and Wilson (1970) compared root elongation at low temperature among cheatgrass, medusahead, bluebunch wheatgrass and crested wheatgrass. Rapidly elongating cheatgrass and medusahead roots penetrated the soil ahead of bluebunch wheatgrass and used available moisture. Results were similar to those found by Harris (1967) comparing cheatgrass and bluebunch wheatgrass. In contrast, crested wheatgrass roots penetrated the soil almost as rapidly as the two annual grasses and remained in favorable moisture (Harris and Wilson 1970). The differences in root penetration resulted in lower leaf water potentials and poorer survival in bluebunch wheatgrass than in crested wheatgrass. Results suggested that in areas where root growth occurs at low temperatures and where lands are infested with cheatgrass and medusahead (e.g. Great Basin and Columbia Plateau), seedlings of a plant such as crested wheatgrass would be more successful than seedlings of a plant such as bluebunch wheatgrass.

Medusahead germinates and grows earlier than cheatgrass and its root anatomy adapts it for a later phenology. Medusahead is also adapted to higher temperatures, as indicated by germination and root growth reactions. Harris (1977) demonstrated that medusahead germinates significantly faster and more completely than cheatgrass under conditions of relatively low water potentials (-0.5 to -1.O MPa) and variable temperatures (10 to 30°C). Medusahead roots have a larger diameter than cheatgrass roots and medusahead cell walls are thicker than those of cheatgrass. Cheatgrass senesces earlier than medusahead because its root system is poorly protected against droughty soils. The endodermal layer is thin and the root poorly adapted to translocate water through the dry, hot upper soil layer in summer conditions (Harris 1977). Medusahead primary and adventitious root phenology is comparable with or earlier than that of cheatgrass, so medusahead seedlings compete successfully with cheatgrass seedlings (Harris 1977).

Hironaka (1961, oral presentation at Symposium: Ecology, management and restoration of intermountain annual rangelands, Boise, ID, May 1992) has suggested that later maturation by medusahead restricts it to the 10-inch and above precipitation zones of the cheatgrass type and below 5000 feet in the northern Great Basin. According to Hironaka (1961), medusahead requires residual soil moisture following cheatgrass maturation to be able to complete its growth. However, root morphology differences noted by Harris (1977) suggest that medusahead may be able to extract needed soil moisture to a lower water potential than cheatgrass and perhaps may not be restricted to wetter sites (i.e. greater than 10 inches annual precipitation).

Evans et al. (1970) and Evans and Young (1977) have stated that on cheatgrass dominated sites, virtually no perennial grasses would be established without weed control. During average or above-average precipitation years, initial precipitation is sufficient to provide available seedbed moisture, but with annual weed growth this moisture is soon exhausted and becomes unavailable to perennial grass seedlings. Goebel et al. (1988) stated that even the relatively competitive 'Secar' bluebunch wheatgrass *(Agropyron [Pseudoroegneria] spicatum)* will not establish when in competition with medusahead without control of medusahead (and other annuals).

Adapted Species and Proper Techniques

Haferkamp and Miller (1988) concluded that reseeding rangelands has a high risk, and even though projects are designed and conducted utilizing the best available methods of seedbed preparation and planting, failures can occur when the environmental stress (i.e. dry soil) is too great. The potential for success can be enhanced by paying particular attention to site selection, selecting adapted species with good seedling vigor, preparing a firm weed-free seedbed, and planting at the proper season with the proper equipment.

Van Epps and McKell (1983) concluded that intense plant competition from weedy annual species has a negative influence on the survival and growth of perennial plant species transplanted either as bare-root or container-grown stock. Plant species most likely to survive are those which can endure competition from annual plants. Effects of reduction of competition are generally reflected in greater plant height and cover. Plant species most likely to withstand competition are those best adapted to a site. Species poorly adapted to a site apparently are not able to respond to the improved control of competition. Improved establishment of site adapted plants in arid sites appears to be possible by controlling competition of annual weedy forbs and grasses for a period of one or two years. Three or more growing seasons may be needed to evaluate the permanent establishment of plants under arid conditions. Plants under uncontrolled competition appear to stabilize their survival rate by the end of the third year. Springfield (1970) reported that survival of fourwing saltbush transplants, in the Southwest under no competition, stabilized during the fourth year following field planting, while the survival rate of those growing in competition with grass was still declining in the fifth year.

There are large variations among species as to the negative impact of plant competition on plant survival and growth. Prostrate summer cypress *(Kochia prostrata),* an exotic perennial, was noticeably more successful in its establishment success than fourwing saltbush, winterfat, or Russian wildrye in studies conducted by Van Epps and McKell(1983). We suspect that variation in competitive ability exists in native species as well.

Plant establishment is governed not only by seed and seedling autecology, but by synecological interactions among plants during the establishment phase (Samuel and DePuit 1987). Competition during the seedling stage can strongly influence plant establishment. The nature of this influence is governed by an interacting array of plant related and external factors. Success in range seeding depends in part upon proper understanding of the effects of competition during the establishment phase and the factors that modify this phenomenon. Competition and its influence can be manipulated by appropriate modification of both plant related and external factors.

B. Climate Change and Competition

Ozone Depletion

According to Caldwell et al. (1989), ozone depletion and the resulting increase in solar UV-B radiation may have numerous consequences including photochemical, tissue, whole plant and community effects, most of which are not at all well understood. Although many of these factors could potentially be affected by increased UV-B radiation, field studies are rarely able to detect effects because field conditions appear to buffer these effects (Caldwell et al. 1989). Therefore, ozone-depletion and UV-B radiation increase is not likely to have a major impact on rangeland ecosystems.

CO_2 Enrichment

Results of experiments by Zangerl and Bazzaz (1984) suggested that CO_2, enrichment can significantly affect plant communities. The effects were most consistent for whole community attributes, less so for groups of species and still less for individual species. Overall community production increased with CO_2, enrichment C3 species increased in dominance relative to C4 species, often, but not always, independent of light and nutrient availability. At the individual species level resutts were much more varied and often depended upon the availability of resources other than CO_2. The authors found that CO_2 enrichment affected vegetative biomass production differently from seed biomass production, that the relative allocation of resources to seed vs. leaves and stems was affected, and that, contrary to expectation, individual C4 species could benefit from CO_2 enrichment. The authors postulated that relative success of species in a community will be affected by shifts in availability of CO_2. However, later successional communities where species compete less with one another may be less affected than earlier successional communities where many species have broad niche overlap. Also, species of later successional communities have greater leaf resistances and may be expected to be less sensitive to an increase in CO_2, but this is not the case for the sagebrush steppe where the dominant perennial species have high conductances, high photosynthetic rates and would be expected to respond to high CO, concentrations (e.g. Caldwell et al. 1977, Caldwell et al. 1981).

Mayeux et al. (1991) have hypothesized that favorable effects of increasing CO, that apply to all functional groups of plants, especially improved water use efficiency and amelioration of stress, suggest that overall productivity of rangelands will increase. However, increased productivity will probably continue to be reflected in increased biomass of less desirable C3 weeds and woody vegetation, as opposed to C4 warm-season perennial grasses, where the two functional groups occur together. It also seems reasonable to expect improved productivity of C3 cool-season grasses, and to consider whether increasing atmospheric CO_2 is influencing ecosystem structure and function in environments where they predominate. Citing several other sources, Mayeux et al. (1991) stated that woody plants respond to elevated CO_2 to the same or greater extent as C3 herbs. There is a need for research to examine the role of elevated CO_2 to favor components of the ecosystem to such a degree that management must be concerned about shifts in species composition.

Greenhouse Effect (Global Warming)

Most general circulation models of global warming predict warmer temperatures and midcontinental drying (Office for Interdisciplinary Earth Studies/UCAR 1991). One of the research priorities identified by the workshop on *Arid Ecosystems interactions* (Office for Interdisciplinary Earth Studies/UCAR 1991) was to conduct fundamental research into physiology and growth of vegetation in arid and semiarid regions and its response to the changing climate. Studies of vegetation response should include both field experiments and modeling. Experiments should be designed to preview effects of environmental changes and in temperature and precipitation and to provide rigorous tests of process models.

C. Controlling Competition

Undesirable plants and noxious weeds occupy many range sites and their populations are increasing dramatically. In some cases noxious weeds have also invaded and become established on sites considered to be in “Excellent” condition and on Wilderness Study Areas. Control of undesirable plants, including noxious weeds, is necessary to stop their spread and to facilitate restoration of impacted sites with native species.

Physiological stage of growth is a primary factor determining effective treatment periods for control of problem plants. Since an annual completes its life cycle in one year, reproduction of annuals is dependent on seed production with few exceptions. Thus, most control programs for annuals are aimed at the prevention of seed production. This is accomplished by killing the plants prior to or during early flowering. Preventing seed production is often an important consideration with perennial plants also, but may not be ultimately successful in controlling the undesirable. Methods that completely remove plants from the soil, such as grubbing or removal by power equipment, effectively kill most plants at any stage of growth (Vallentine 1989).

Perennial plant control methods that are based on the removal of top growth (e.g. cutting, mowing, grazing, or chemical defoliation) are normally most effective when the plant’s food reserves and ability to produce regrowth are at their lowest point (Vallentine 1989) and may require multiple applications for successful control.

In addition to the listed official noxious weeds of the states included in the project area, plant species considered to be of concern and in potential need of control in selected situations include: sagebrush, juniper, cheatgrass, medusahead, and the knapweeds.

Sagebrush

In areas of high sagebrush cover, there is essentially no way to reestablish native, or introduced, herbaceous cover without first removing some of the dense sagebrush canopy (Winward 1991). Reestablishment of a more natural ecological balance in the overstory/understory in most sagebrush ecosystems will require a much greater effort at restoring some of the natural mosaic of sagebrush canopies that is thought to have existed prior to European settlement of the west. To accomplish this, a long-term program will be needed that will allow periodic, patterned removal or thinning of sagebrush.

Juniper

The June 1991 BLM Western Juniper Working Group report to the Oregon/Washington Management Team on expansion of western juniper in eastern Oregon stated that western juniper is expanding over vast areas of BLM rangelands in eastern Oregon at an alarming rate and the area of total juniper domination is rapidly becoming larger. A projected result is an inability to meet the land use objectives of maintaining or improving ecological status, improving biological diversity and maintaining or improving wildlife habitat and watershed stability. Degradation of water quality, loss of productivity, increased erosion, and nutrient tie-up are also listed as problems resulting from juniper encroachment. Fire is believed to have played a major role in regulating the amount of juniper in the eastern Oregon area. Fire or some other intervention is necessary to inhibit juniper encroachment. The most effective control can be achieved by intervention in areas of encroachment while the trees are four feet tall or less, at which stage they are more susceptible to control and they have probably not yet severely suppressed understory vegetation.

Cheatgrass

Much of the sagebrush-steppe of western North America has been converted to an annual grassland dominated by introduced species (Whisenant 1990). Cheatgrass is the dominant species on more than 100 million ac (40 million ha) of the Intermountain West (Mack 1981). The sagebrush-steppe of Idaho's Snake River Plains probably evolved with fire-return intervals of 35 to 100 years (Whisenant 1990). With the introduction of cheatgrass and domestic livestock, the fire-return interval decreased to between 2 and 4 years on many sites. This has converted millions of acres from sagebrush-steppe to annual grasslands dominated by introduced species. Species richness dramatically decreased at several spatial scales of resolution as these fires became larger, more uniform, and more frequent (Whisenant 1990). Revegetation efforts on these areas will be largely ineffective until fire sizes and fire frequencies are greatly reduced. Therefore, collaboration is necessary with the Intermountain Greenstripping and Rehabilitation Research Project (IGRRP) since the main focus of IGRRP is to reduce the size and frequency of fires (Pellant 1990).

Noxious Weeds

"Noxious Weed" means any weed designated by a state that is injurious to public health, agriculture, recreation, wildlife, or any public or private property. Noxious weeds have become so thoroughly established and are spreading so rapidly on state, county, and federally-owned lands, as well as on private land, that they have been declared by state laws (e.g. ORS 570.505 in Oregon) to be a menace to the public welfare. Steps leading to eradication, where possible, are necessary. It is further recognized that the responsibility for such eradication and/or intensive control rests not only on the private landowner and operator, but also on the county, state, and federal governments. Weeds designated as noxious are listed by state in Appendix F.

Plant Control by Fire

Several undesirable plants are selectively controlled by burning when the combination of plant growth stages and environmental factors including soil moisture is ideal. However, repeated burning can seriously deplete root reserves of desirable perennials and even cause their death, particularly in semiarid areas. Season of burning and phenological stage of growth directly affect plant response to burning, with each plant species responding somewhat differently (Daubenmire 1968, Wright et al. 1979, Vallentine 1989).

Vallentine (1989) summarized the plant and environmental factors known to affect the tolerance, resistance, or avoidance of damage to plants exposed to fire.

Plant factors reducing fire damage	Plant factors increasing fire damage
Sprouting ability	Nonsprouting
Rhizomes deep in soil	Rhizomes absent or shallow or stolons only
Fibrous roots deep	Fibrous roots shallow or above mineral soil
Growing points at or below ground level	Growing points above ground level or elevated
Tolerant of herbage removal	Intolerant of herbage removal
High storage CHO reserves	Low storage CHO reserves
Bark thick (with ground fire)	Bark thin (with ground fire)
Foliage elevated (with ground fire)	Low foliage (reached by ground fire)
Plants dormant	Plants actively growing
Low accumulation of tuft	High basal leafage accumulation

Environmental factors reducing fire damage	Environmental factors increasing fire damage
Low ground debris level	High ground debris level
High moisture content in plant base and mulch	Low moisture content in plant base and mulch
Moist soil (good vigor plants)	Dry soil (low vigor plants)
Short-duration fire (moves rapidly)	Long-duration fire
Prior herbage removal	Ungrazed (i.e., added fine fuel)
Vigor not reduced by prior insect, disease, mechanical, or chemical damage	Vigor reduced by prior treatment

Damage by fire to desirable herbaceous plants in the sagebrush zone is fairly low, with the exception of Idaho fescue. Idaho fescue, in contrast to bluebunch wheatgrass, is very leafy and compacted at the base, where dead material accumulates as fuel (Vallentine 1989). The high density of material at the base of the plant results in higher temperature and increases the probability of the plant's death when burned. Many palatable shrubs such as sagebrush, curlleaf mountain mahogany, cliff rose, and bitterbrush are susceptible to damage by fire.

Repeated burning, or burning in late summer, strongly favors cheatgrass when cheatgrass is present in the interspaces among native perennials. If cheatgrass rapidly stabilizes at high densities following burning, the site will be mostly closed to seedlings of perennial grasses (Young and Evans 1978). This has resulted in a conversion to nearly pure stands of cheatgrass (Bunting et al. 1987). Cheatgrass is often abundant in stands of Wyoming big sagebrush that have sparse understories of native species in western Idaho, northern Nevada, and eastern Oregon. Burning these communities will remove brush, but it will not provide more perennial grass where cheatgrass has become dominant. The annual grass stage is relatively stable with bottlebrush squirreltail *(Sitanion* hystrix) being the primary perennial grass to increase on the more arid sites. Once an area burns and becomes dominated by cheatgrass, the risk of wildfire becomes much greater (Hironaka et al. 1983) and the likelihood of conversion back to perennial grasses by natural regeneration is greatly diminished (Bunting et al. 1987). Where cheatgrass is more than half of the understory of the area or the area cannot be protected against subsequent accidental burns, big sagebrush sites should not be burned (Pechanec and Stewart 1954).

Annuals such as cheatgrass *(Bromus tectorum)* are very tolerant to fire because the seed is resistant to fire. Moreover, cheatgrass burns in June or July after seed dispersal and death of the adult, but leafy perennials that are still actively growing can be killed. Thus, frequent fires in early to mid summer will promote cheatgrass. Medusahead has a seedhead moisture content above 30% for approximately a month after the leaves and stems begin to dry and provide a sufficient volume of fuel to carry a fire. While the seed moisture content is still high (soft dough stage), medusahead seed is readily killed by high temperatures. Burns at this stage of growth are recommended in the afternoon when burning slowly into a mild wind to achieve sufficient heat (McKell et al. 1962). Medusahead seed is not viable until awns begin to curl. Burning after medusahead seeds shatter and fall to the ground is ineffective (Vallentine 1989). If too few perennial grasses are in the understory of sagebrush-annual grass communities, major renovation, including seeding, will be needed to restore a community to a sagebrush-perennial grassland.

Burning has been an effective, economic control of nonsprouting juniper where a uniform burn has been obtained (Vallentine 1989). Broadcast burning of live juniper trees requires a dense stand of trees (400 or more per acre) or a flammable understory to be effective (Arnold et al. 1964). Burns in pinyon-juniper have often burned clean on flat or gently rolling terrain but have left islands of unburned trees on hills and ridges where the junipers grow in a thin stand with few understory plants. Large juniper trees often provide their own firebreak zone through intensive competition, and grazing further removes the flammable understory. Grasslands being invaded by junipers can be broadcast burned to control the junipers before the herbaceous understory is reduced to the degree it will not carry a uniform burn, however, caution must be used if fire-intolerant shrubs and herbaceous plants are also found in the stand. Nonsprouting juniper seedlings and saplings are readily killed under these conditions, and even sprouting junipers may be materially suppressed (Vallentine 1989). Following intense wildfires in the pinyon-juniper type in central Utah, big sagebrush often became dominant by 11 years later, with juniper beginning to appear shortly thereafter (Barney and Fischknecht 1974). Juniper often became prominent after about 46 years and dominant at about 70 years. Once dominant, broadcast burning becomes difficult except under hazardous dry, hot, and windy conditions.

Wyoming big sagebrush occurs on the most arid areas within the range of big sagebrush. Annual precipitation may average less than 7 inches in some communities (Hironaka et al. 1983). Low productivity and a resultant lack of fine fuels of these areas often make prescribed burning difficult (Schmisseur and Miller 1985, Bunting et al. 1987). Wyoming big sagebrush cover seldom exceeds 25%, which contributes to the difficulty in getting a fire to carry through such communities. If the canopy cover criterion is satisfied, it is important to have at least 250 pounds of fine fuel per acre to carry the fire. Low sagebrush areas are not likely candidates for prescribed fire because fire will not easily move through low sagebrush (Schmisseur and Miller 1985).

Wright (1985) discussed the effects of fire on grasses and forbs in sagebrush-grass communities. Effect of fire on grasses is largely determined by season of burn, size of plant, amount of dead material, growth form, species, precipitation, and whether it is an annual or perennial. June or July is the most detrimental time to burn bunchgrasses. Before or after these months, fire is less detrimental. Spring burns (April) are less detrimental than fall burns (September-October), although most species recover from fall burns in 1 to 3 years. Native plants with small canopies of loosely arranged stems are more resistant to fire than larger plants. Rhizomatous species such as *Agropyron dasystachyum* and A. *smithii* tolerate fire well. Seral species such as *Poa sandbergii* and *Sitanion hystrix* also tolerate fire quite well at any time of the year. Leafy bunchgrasses *(Stipa, Fescue)* are slower to recover than stemmy bunchgrasses *(Agropyron* spp., *Elymus, Sitanion).* Early maturing species *(Poa sandbergii* and *Bromus tectorum)* tolerate summer fires well.

Most forbs tolerate fire well if burned in spring or fall. Only forbs that remain green throughout the year, such as *Eriogonum* spp., are severely hurt by prescribed burns. Perennial forbs usually fully recover by the end of the second growing season. Fire can enhance the number and diversity of forbs because they have hard seed that can be scarified by a fire (Wright 1985).

Using information from Wright et al. (1979), Schmisseur and Miller (1985) prepared tables (tables 1 - 3 below) identifying relative responses to burning of some Great Basin and Columbia-Snake River Plateau range grasses, forbs, and shrubs. Relative severity of fire effects is largely dependent on season of burn. Wright et al. (1979) provide a literature review of fire effects that yield more detailed information, particularly with regard to grasses and shrubs, than can be gleaned from tables 1-3. The Fire Effects Information System (FEIS) developed by the Forest Service at the Intermountain Research Station's Fire Sciences Laboratory in Missoula, MT is another tool available to obtain information about fire's effects on plant or

Table 1. Relative Response of Some Great Basin and Columbia-Snake River Plateau Range Grasses to Burning. For species with two scientific names, the upper scientific name represents the Hitchcock (1971) taxonomy, while the lower name represents the Barkworth and Dewey (1985) classification of the Triticeae.

Severely Damaged	Slightly damaged	Undamaged
Needle-and-thread *(Stipa comata)*	Bluebunch wheatgrass *(Agropyron spicatum)* *(Pseudoroegneria spicata)*	Cheatgrass *(Bromus tectorum)*
Threadleaf sedge *(Carex filifolia)*	Big bluegrass *(Poa ampla)*	Crested wheatgrass *(Agropyron desertorum)*
Thurber needlegrass *(Stipa thurberiana)*	Columbia needlegrass *(Stipa columbiana)*	Douglas sedge *(Carex douglasii)*
	Cusick bluegrass *(Poa cusickii)*	Intermediate wheatgrass *(Agropyron intermedium)* *(Elytrigia intermedia)*
	Idaho fescue *(Festuca idahoensis)*	Plains reedgrass *(Calamagrostis montanensis)*
	Indian ricegrass *(Oryzopsis hymenoides)*	Prairie junegrass *(Koeleria cristata)*
	Nevada bluegrass *(Poa nevadensis)*	Pubescent wheatgrass *(Agropyron trichophorum)* *(Elytrigia intermedia* subspp. *barbulata)*
	Squirreltail *(Sitanion hystrix)*	Riparian wheatgrass *(Agropyron riparium)* *(Elymus lanceolatus)*
		Sandberg bluegrass *(Poa sandbergii)*
		Tall wheatgrass *(Agropyron elongatum)* *(Thinopyrum ponticum)*
		Thickspike wheatgrass *(Agropyron dasystachyum)* *(Elymus lanceolatus)*
		Western wheatgrass *(Agropyron smithii)* *(Pascopyrum smithii)*

Table 2. Relative Response of Some Common Great Basin and Columbia-Snake River Plateau Forbs to Burning.

Severely damaged	Slightly damaged	Undamaged
Hairy fleabane *(Erigeron concennus)*	Astragalus *(Astragalus* spp.)	Arrowleaf balsamroot *(Balsamorhiza sagittata)*
Hoary phlox *(Phlox canescens)*	Matroot *(Penstemon radicosus)*	Common camandra *(Commandra umbellata)*
Littleleaf pussytoes *(Antennaria microphylla)*	Munro globemallow *(Sphaeralcea munroana)*	Common sunflower *(Helianthus annuus)*
Low pussytoes *(Antennaria dimorpha)*	Northwestern paintbrush *(Castilleja angustifolia)*	Coyote tobacco *(Nicotiana attenuata)*
Mat eriogonum *(Eriogonum caespitosum)*	Pinnate tansymustard *(Descurainia pinnata)*	Douglas knotweed *(Polygonum douglasii)*
Uinta sandwort *(Arenaria uintahensis)*	Plumeweed *(Cordylonthus ramous)*	Flaxleaf plainmustard *(Sisymbrium linifolium)*
Wyeth eriogonum *(Eriogonum heracleoides)*	Red globemallow *(Sphaeralcea coccinea)*	Flaxweed tansymustard *(Descurainia sophia)*
	Sticky geranium *(Geranium viscossissimum)*	Foothill deathcamas *(Zigadenus paniculatus)*
	Tailcup lupine *(Lupinus caudatus)*	Gayophytum *(Gayophytum diffusum)*
	Tapertip hawksbeard *(Crepis acuminata)*	Goldenrod *(Solidago* spp.)
	Tongueleaf violet *(Viola nuttallii)*	Goosefoot *(Chenopodium* sp.)
	Tumblemustard *(Sisymbrium altissimum)*	Lambstongue groundsel *(Senecio integerrimus)*
	Wavyleaf thistle *(Circium undulatum)*	Longleaf phlox *(Phlox longifolia)*
	Whitlowort *(Draba verna)*	Orange arnica *(Arnica fulgens)*
	Wild lettuce *(Lactuca* sp.)	Pale alyssum *(Alyssum alyssoides)*
		Purpledaisy fleabane *(Erigeron corymbosus)*
		Russian thistle *(Salsola pestifer)*
		Velvet lupine *(Lupinus leucophyllus)*
		Western yarrow *(Achilles lanulosa)*
		Wild onion *(Allium* sp.)

Table 3. Relative Response of Some Common Great Basin and Columbia-Snake River Plateau Shrubs to Fall Burning.

Severely damaged	Slightly damaged	Undamaged
Antelope bitterbrush *(Purshia tridentata)*	Curlleaf mahogany *(Cercocarpus ledifolius)*	Ceanothus (sprouting) *(Ceanothus* sp.)
Big sagebrush *(Artemisia tridentata)*	Desert bitterbrush *(Purshia glandulosa)*	Common snowberry *(Symphoricarpos albus)*
Black sagebrush *(Artemisia nova)*	Mountain mahogany *(Cercocarpus montanus)*	Gambel's oak *(Quercus gambelii)*
Broom snakeweed *(Xanthocephalum sarothrae)*	Mountain snowberry *(Symphoricarpus oreophilus)*	Horsebrush *(Tetradymia canescens)*
Ceanothus (nonsprouting) *(Ceanothus* sp.)	Serviceberry *(Amelanchier alnifolia)*	Rabbitbrush *(Chrysothamnus* sp.)
Cliffrose *(Cowania mexicana)*	Silver sagebrush *(Artemisia cana)*	
Low sagebrush *(Artemisia arbuscula)*		
Three-tip sagebrush *(Artemisia tripartita)*		

animal species or plant communities. As of June 1992, the system had information on about 500 plant species, 30 wildlife species, and 10 plant ecosystems. Plans are to add species and ecosystems to the system over the next several years. The BLM has installed the FEIS on computer at the Boise Interagency Fire Center (BIFC). For assistance in accessing the BIFC computer, BLM employees can contact their District Information Resource Manager, or Branch of Fire Science, BIFC, at (208) 389-2456. Forest Service employees should contact their local DG system manager to access the system. State agency employees should contact their designated Fire Effects System coordinator, or their local Forest Service cooperative fire manager.

Potential Drawbacks to Burning

All planning for use of prescribed fire must take into consideration the Clean Air Act (P.L. 95-95) and the public interest (Kilgore and Heinselman 1990 citing Ferry et al. 1985). Although prescribed fire may be an efficient method of meeting management objectives, short-term effects of fire on air quality may violate certain air quality standards. The Environmental Protection Agency (EPA) has developed National Ambient Air Quality Standards (NAAQS) for six air pollutants, including particulate matter. The Clean Air Act requires all federal agencies to comply with all federal, state, and local air quality regulations (Kilgore and Heinselman 1990 citing Haddow 1985). Proposed standards for particulates will include both inhalable and respirable particulates, much smaller sized particles than previous standards have addressed. Most smoke particulates emitted from prescribed burning are in these small size classes (Kilgore and Heinselman 1990). Airborne particulates are the primary pollutant of wildfires and prescribed burns and account for 23.7 percent of all particulates emitted into the atmosphere (Wright and Bailey 1982, Martin et al. 1977). The most objectionable feature may be the effect on visibility which is, however, generally short-lived. Large particles settle out rapidly, but small particles may remain suspended for several days

(Martin et al. 1977). The effect of small particles on humans may not be as innocuous as once thought, but the effects remain unclear (Sandberg et al. 1979).

The issue of field burning has surfaced in the region recently (Dewey Rand Jr. commentary, June 26, 1992, Capital Press, Salem, OR). An organization called AIR (Air Improvement Resolve), based in La Grande, OR, has submitted an initiative petition to phase out burning of all crop fields in three years and prohibit slash burning after Jan. 1, 1993. The petition has been submitted in a largely agricultural county lacking heavily populated cities and urban areas, such as in the Willamette Valley, Oregon, where smoke from field burning has become a major political issue. Use of fire to establish and maintain "natural" ecosystems on public lands may face similar opposition.

Mechanical Control

Mechanical plant control is an alternative to chemical, biological, or fire control methods (Vallentine 1989). It can also be combined with one of the alternative approaches, either as a preparatory or follow-up treatment, or two different mechanical methods may be combined to accomplish the desired treatment (Vallentine 1989).

Vallentine (1989) listed the following key factors that should be considered in selecting the best mechanical method for a specific plant control job:

1. *Management objectives* - what is the primary use as well as other multiple uses; is selective or total plant control being sought; will the release and/or rejuvenation of desirable, residual plant species be sufficient, or is simultaneous seedbed preparation and artificial revegetation planned.

2. *Characteristics of target* species - density, height, diameter of stem, growth form, brittleness, and sprouting ability.

3. *Characteristics of secondary species* - whether desirable plant species will be released; whether potentially undesirable plants may increase or invade; or whether all resident species need to be replaced.

4. *Topography and terrain* - roughness, steepness, heterogeneity, erodability, and amount of woody debris on the ground.

5. *Kind of soil* - depth; fertility; soil moisture relationships; amount, size, and attachment of rock; and degree of soil compaction.

6. *Site potential* - anticipated cost-benefit ratio; productivity versus rehabilitation.

7. *Follow-up required-* how long will benefits last; what other treatment must follow; what maintenance will be required.

Several mechanical methods can successfully control sagebrush. Plowing or disking will destroy sagebrush and prepare a good seedbed for revegetation where there is not an adequate understory of desirable perennials. Beating or shredding will destroy aboveground portions of plants by cutting, beating, or shredding and will leave a coarse layer of litter on the ground surface. Railing will uproot or break off sagebrush on level, rock-free sites where the sagebrush is large and brittle. Chaining is an effective, economical, and widely applicable method for thinning stands of big sagebrush and releasing grasses and forbs. It was originally developed for eliminating stands of pinyon and juniper, but has also been used successfully for controlling many other woody species. If an adequate understory is not present, a modified chain may be used to prepare a good seedbed. Pipe harrowing has been used to thin low, brittle brush. It is adapted to rocky sites and rough terrain where more effective machinery is not adapted, and provides sufficient soil scarification to cover broadcasted seed on rocky scablands, burns, abandoned roads, or excavation scars (Blaisdell et al. 1982, Vallentine 1989).

Plummer et al. (1968) described interseeding (seeding directly into established vegetation usually with only partial reduction of competition) as a widely successful means of improving vegetal cover. Using drills provided with 6 to 24 inch wide scalpers that effectively eliminate cheatgrass and cluster tarweed is a satisfactory means of seeding shrubs and perennial herbs in competitive annual types. Interseeding is also effective in establishing shrubs and forbs in perennial grass stands.

Haferkamp et al. (1987) found a land imprinter to be effective in providing seed-soil contact for broadcast seeds on loose or coarse textured soils. They suggested the need for prior seedbed preparation, designed to control competing vegetation, in the northern Great Basin or Palouse Prairie.

The basic mechanical weed control options for cheatgrass are spring tillage followed by seeding, or spring tillage with a summer fallow maintained until fall seeding (Evans and Young 1987). The primary difference between the two is that the fallow period conserves and stores moisture and allows soil nitrate to accumulate. Moisture and nitrate availability both interactively influence the establishment of perennial grass seedlings. Too much nitrate will produce more harm than good in dry years and when cheatgrass control is not complete enough to prevent preemption of available water and nitrate by weeds (see also McLendon and Redente 1991).

The problem with mechanically maintained fallows centers on the occurrence of alternate floras that are conditioned by summer moisture events. Russian thistle is a major problem on fallows. If the summer stays dry, no follow-up mechanical weed control will be necessary. If repeated summer rains occur, subsequent weed control will be necessary (Evans and Young 1987).

According to Evans and Young (1987), the implement most adapted to spring tillage is a light disk harrow with minimum draft requirements. Complete turnover of the seedbed would give maximum establishment of perennial grass stands. However, this is not practical on most rangeland sites and may not be economically feasible even on sites where it is physically possible. Tillage for weed control on rangelands seldom involves secondary tillage to enhance seedbed quality. However, a small amount of time spent in additional seedbed preparation may mean the difference between seeding stand success or failure.

Herbicide Control

Herbicides are an effective, necessary, and environmentally sound tool for the control of weeds and brush on rangelands when properly used (Young et al. 1981). As a result, chemical control has been a widely used means of removing unwanted or noxious plants from rangeland (Vallentine 1989).

Herbicidal control has distinct advantages over other plant control methods which explains their widespread use (Vallentine 1989). These general advantages include: (1) herbicides can functionally be used where mechanical methods are impossible, such as on steep, rocky, muddy, or many timbered sites, particularly with aerial application; (2) they provide a variety of application methods ranging from individual plant treatment to aerial broadcasting; (3) they provide a rapid control method from the standpoint of both plant response and acreage covered when broadcast applied; (4) they have low labor and fuel requirements for application; (5) phenoxy herbicides are generally cheaper than mechanical control methods, but may cost more than prescribed burning; (6) most herbicides are selective or can be selectively applied so that damage to desirable plant species can be minimized; (7) herbicides can maintain a grass and litter cover which reduces soil exposure to erosion; (8) they are safe and reliable when proper safeguards are followed; (9) they can often utilize regular farm and ranch spray equipment; (10) soil-applied, but not foliage-applied, herbicides can be applied over a relatively long time period for brush control.

Disadvantages of using chemicals to control undesirable range plants include the following (Vallentine 1989): (1) no chemical control has yet proven fully satisfactory for some noxious plant species; (2) herbicides provide a desirable, noncompetitive seedbed for artificial seeding only under certain situations; (3) cost of control may outweigh expected benefits on low-potential range. This is also true of many other treatment methods; (4) the careless use of chemicals can be hazardous to nontarget plants in the stand and to cultivated crops or other nontarget sites nearby, or may contaminate water supplies; (5) lack of selectivity may result in killing associated forbs and shrubs important for livestock and/or wildlife; (6) the effective time period for applying foliage-applied herbicides is usually quite restricted.

Vallentine (1989) referenced several proven uses for herbicides on rangelands. Herbicides have provided selective control of undesirable plants as a sole treatment, for example, control of green rabbitbrush growing with grasses on foothill sites with 2,4-D plus picloram (Evans and Young 1975), or removing big sagebrush from bitterbrush and serviceberry sites with clopyralid (Whisenant 1987). They have released closed communities over which undesirable woody or even herbaceous plants have gained dominance, for example, juniper invasion on deep-soil benches (Evans et al. 1975). Herbicides can be used to rejuvenate tall shrubs and low trees for big game by top killing and stimulating new growth from sprouts and seedlings, for example, old-growth aspen stands given light rates of 2,4-D (Harniss and Bartos 1985). They are used to eradicate small infestations of serious plant pests or “environmental contaminants” (spotted knapweed, musk thistle, etc.) not previously found locally. Paraquat and 2,4-D have been used on sagebrush-cheatgrass sites to achieve total plant kill to meet the needs of chemical seedbed preparation for range seeding or planting. Herbicides have been applied postplanting to enhance establishment by selectively controlling weed competition (e.g. dense annual broadleaf weeds or perennial ragweed in a new range seeding). Currie et al. (1987) applied atrazine at 0.5 pound/acre to remove annual bromes from perennial wheatgrass or Russian wildrye stands. (Note: Atrazine labelled for rangeland use is not currently being marketed.)

Chemical Seedbed Preparation

The following discussion of chemical seedbed preparation is primarily from Vallentine (1989). Herbicides have been successfully used as the sole treatment in seedbed preparation. Seeding is done shortly after spraying or after a fallow period maintained by herbicides. The techniques have been made feasible by the development of effective herbicides, improved application methods, and the rangeland drill and selected no-till drills. The best herbicide or combination of herbicides and a multitude of application and timing factors must be carefully evaluated.

Chemical seedbed preparation and direct seeding require that (1) the competing, resident vegetation be killed or adequately suppressed and (2) the herbicide(s) applied be broken down or leached away by the time seeded species germinate or are not toxic to seedlings of the seeded species (Eckert and Evans 1967). Chemical fallow during the previous growing season has been more successful on low-rainfall sites than spring herbicide treatment and direct seeding (Young et al. 1969).

In May 1991, BLM issued its Final EIS on vegetation treatment on BLM lands in 13 western states using integrated pest management methods (Final Environmental Impact Statement Vegetation Treatment on BLM Lands 1991). Use of selected herbicides was included within the EIS. Herbicides cleared for use on BLM lands are identified in Appendix M of the EIS. In the following discussion of specific chemicals, if a chemical discussed is not included in Appendix M of BLM's Final EIS for Vegetation Treatment on BLM Lands in Thirteen Western States, its absence from the list will be noted. Permission to use chemicals not listed in EIS Appendix M will be difficult to obtain, particularly if a chemical listed in EIS Appendix M can be used in its place. To the best of our knowledge, the chemicals listed in EIS Appendix M are allowed for use on BLM administered lands in the thirteen western states included within the EIS (does not include California or western Oregon) if treatments are conducted in accordance with BLM procedures in Chemical Pest Control (USDI, BLM Chemical Pest Control Manual, Handbook H-901 l-l). Currently, Oregon and Washington are under a court injunction and are under further restrictions. Contact the BLM Oregon State Office for further information if herbicide use on BLM lands within Oregon or Washington is contemplated.

2,4-D - Aerial spraying with 2,4-D and drilling with a rangeland drill have been effective for establishing additional perennial grasses on sagebrush-grass and weedy forb-grass sites with a fair understory of perennial grasses. This approach has been particularly effective when the undesirable forbs and shrubs are readily killed by 2,4-D and annual grasses have not become a problem. A second herbicide application may be required in the spring of the establishment year if sprouting shrubs such as rabbitbrush are present or a large number of sagebrush seedlings develop. A disadvantage of this technique is that it tends to remove desirable forbs as well as the targeted shrubs.

Paraquat - (Paraquat is *not* listed in Appendix M of the Vegetation Treatment EIS noted above) Paraquat application at 0.5 to 1.0 pound acid equivalent per acre (a.e./A) in the spring after emergence of annual bromes and drilling immediately afterward have been an effective method of establishing perennial grasses in the Intermountain Region (Young et al. 1984). Paraquat is very quick acting, leaves no soil residues, and permits planting of perennial grasses immediately after spraying (National Research Council 1968). Paraquat sprayed in the spring at rates as low as 0.5 pounds per acre has given adequate and consistent control of cheatgrass for establishment of perennial grasses (Evans et al. 1967). Spring paraquat application and seeding has been more effective for cheatgrass control than fall application and seeding in the Intermountain Region, since germination of cheatgrass seed is only partially complete by the time of fall spraying. Paraquat control of cheatgrass has been greatly increased by the use of surfactants (Evans and Eckert 1965). Where broad-leaved weeds and shrubs are growing with cheatgrass, a hormone herbicide such as 2,4-D should be combined with the paraquat application (National Research Council 1968). Paraquat at rates up to 2 pounds has discolored but not killed medusahead (Young et al. 1969). Spraying paraquat in bands in medusahead and drilling down the center of each band has been used successfully to establish Hardinggrass and subclover in California (Kay 1966, Kay and Owen 1970).

Dalapon - Dalapon at 2 to 6 pounds per acre has given excellent control of medusahead where competitive plants were quickly provided by seeding (Young et al. 1969). An effective combination of treatments for establishing wheatgrasses in California medusahead stands has been to burn in late spring, spray with 3 pounds of dalapon early the following spring, spray with one pound of 2,4-D per acre later in midspring, and seeding to wheatgrass in the fall (Torell and Erickson 1967). This combination allows two successive crops of medusahead to be killed before perennial grass seeding. Another promising combination with medusahead has been tillage one year followed by dalapon treatment of medusahead the following year prior to wheatgrass seeding. Dalapon gives only fair control of cheatgrass (Evans et al. 1967, Everson et al. 1969).

(Note: Dalapon was dropped from the list of approved herbicides in the 1991 Final EIS for Vegetation Treatment on BLM Lands in Thirteen Western States because producers were no longer manufacturing formulations registered for control of annual and perennial grasses in non-cropland areas.)

Atrazine - Atrazine gives longer suppression of resident vegetation than does paraquat. When applied at 1 pound per acre in October to control cheatgrass during the following growing season, atrazine has provided good seedbed conditions on semiarid sites in the Intermountain Region for drilling the following October (Eckert and Evans 1967, Young et al. 1969, 1984). Since atrazine is not selective between cheatgrass and perennial grass seedlings, at least one year should be allowed on semiarid lands for dissipation prior to grass seeding. The use of 4-inch-deep furrows aids in the removal of contaminated soil from the seedling environment (Young and Evans 1970). When atrazine is used for chemical fallow, adequate broadleaf control may require spring application of 2,4-D (National Research Council 1968). A fall 1988 atrazine application coupled with removal of atrazine treated soil from drill rows when drilling orchardgrass seed has been successful in controlling yellow starthistle and aiding establishment of orchardgrass on a southwest Oregon foothill site (D.E. Johnson, Dept. of Rangeland Resources, Oregon State Univ., unpublished data). A 2,4-D application the following spring was planned but was not needed for starthistle control.

(Note: Atrazine is no longer labelled for use on rangelands, however, restricted use labelling may be possible and is being pursued.)

Glyphosate - On sites where the perennial resident vegetation is highly competitive, total plant kill rather than temporary suppression will be required. Glyphosate kills a broad spectrum of annual and perennial plant species and has a toxic residual of only 2 weeks or less. Effective resident plant kill is dependent on adequate growth for interception of the herbicide and favorable growth rates for adequate translocation. Not all plant species are completely killed. Adequate carrier must be used to assure that the spray mix reaches the understory plants as well as the overstory plants. To improve effectiveness or reduce application rates otherwise required, glyphosate is commonly mixed with other herbicides before application for maximum plant kill. Drill seeding can take place immediately following the glyphosate application, but delayed drilling for 2 to 3 weeks permits desiccation of the vegetation and easier seeding and also assures no contact of the herbicide with the seed.

Other herbicides - Other herbicides that show promise for chemical fallow or preemergence weed control in range and other pasture seedings include clopyralid, triclopyr, dicamba, and tebuthiuron.

Herbicides can be used in seedbed preparation only when cleared for such usage. James A. Young has recently stated that herbicides are not likely to be available for use on rangelands because of the excessive cost of registering them and the relatively low market demand for herbicides for rangeland conditions (personal communication). The recent loss of Atrazine and Dalapon illustrate the trend toward the reduction in availability of chemicals for rangeland use because the manufacturers are choosing to not register them for such use.

Biological Control

Management practices commonly employed to reduce undesirable plant populations include fire, herbicide application, and mechanical controls such as chaining, brush-beating, and chain sawing. These practices are not always possible, nor are they always effective. Where understory fine-fuels are absent, fires may not carry. In close proximity to dwellings or where air quality is a concern, fire is not always possible. Widespread herbicide use can be hazardous, if used inappropriately or if precautions are not taken, and is becoming less acceptable in our society. Mechanical controls are often quite expensive and not cost-effective on marginally productive lands and are often not feasible on steep or rocky terrain. It may be difficult to receive approval for chemical or mechanical treatments in Wilderness Study Areas. Biological control needs to be considered as an alternative.

Cattle

On mountain summer range in the Intermountain Region, cattle grazing tends to reduce the grass component in the stand and increase the forbs and shrubs (Vallentine 1989). Reduced grazing by cattle has been associated with reduced vigor of bitterbrush and increased vigor of grasses in California (Hubbard and Sanderson 1961). In combination with deer browsing, it has also resulted in senescence and death, without replacement, of aging shrub stands, and secondary succession back to grass-forb dominance along the Wasatch Front in Utah (Urness 1990).

Vallentine (1989) states that observations in a number of areas have suggested that it is advantageous to graze some cattle on range managed primarily for deer when cattle grazing is managed to make maximum use of grasses and minimum use of bitterbrush and other shrubs palatable to deer. Policies of managing state-owned big game range commonly include provision for controlled cattle grazing to promote a better balance of forage species.

Sheep

Proper timing (spring and early summer) and extent of grazing by sheep alone or in combination with cattle has resulted in a thinning of understory forbs and grasses and an increase in the vegetative output of shrubs (Vallentine 1989). Heavy fall grazing after a spring rest from grazing for two or more years in succession was recommended as a range improvement practice on sagebrush-grass range if the perennial grass presence was sufficient to respond. Spring deferment and heavy fall grazing by sheep on native sagebrush-grass range at Dubois, Idaho increased grasses and forbs and decreased sagebrush (Laycock 1961, 1967).

Sheep grazing reduced Klamath weed in California if sheep grazing was concentrated for short periods and continuous heavy grazing was avoided (Vallentine 1989, Murphy et al. 1954). Bedell et al. (1981) and Sharrow and Mosher (1982) demonstrated that sheep could be effective in suppressing tansy ragwort. Lacey et al. (1984) considered sheep grazing effective for suppressing infestations of leafy spurge. Sheep have long been a favorite for general suppression of weeds on ranchsteads, residential estates, and other building sites (Vallentine 1989).

Goats

Because of their ability to utilize and destroy coarse forages, goats are well suited to brush control efforts (Merrill 1975). Goats graze more diverse kinds of vegetation and distribute themselves more evenly than either cattle or sheep (Taylor 1983). Goats have been used in many parts of the world for brush control. They have been used successfully for controlling or suppressing such species as gorse, acacia, eucalyptus, groundsel, Gambel's oak, juniper, shin oak, hackberry, and pricklyash (Richman and Johnson 1992). They are currently being investigated at the U.S. Sheep Experiment Station in Dubois, Idaho for leafy spurge control and are successfully employed on public lands in Montana for that purpose (Richman and Johnson 1992).

In a study in central Oregon, Richman and Johnson (1992) reported that there was strong seasonality of use for plant species, especially shrubs, selected by goats. Big sagebrush and green rabbitbrush were consumed most heavily in the spring by does and in the fall and winter by kids. Fall and winter sagebrush and rabbitbrush consumption by kids was substantial. However, diets consisted primarily of grasses and neither sagebrush nor rabbitbrush were controlled by goats during the study. Although insufficient western juniper was present for valid statistical analysis, observations indicated that juniper was readily eaten by goats with the most energetic consumption occurring in the summer and fall. The several junipers on the site less than 6 feet tall were completely stripped of both foliage and bark. However, some of the juniper were regrowing a year later which indicates a single treatment may not be sufficient for control (Richman personal communication). Martin (1975) concluded that neither goats nor sheep could materially reduce the growth and spread of juniper (among other shrubs) on semidesert ranges in Arizona. Richman and Johnson (1992) felt that because goats are selective browsers and preference for plants changes with season and plant development, they could consume significant amounts of juniper, rabbitbrush, and sagebrush if management strategies could be developed.

Any use of goats must include close control over the herd to prevent the escape of feral goats which have caused major problems in areas such as Australia and New Zealand. These animals will require herding and fencing to prevent escape.

Insects

The biological control process has become increasingly complex; many restrictions have been added and more steps are required for clearing new insect introductions (Vallentine 1989). Employment of biological control of noxious plants by insects has been limited, in part, because of two principal factors (Huffaker 1959): (1) Lack of consensus in acceptance of a plant as undesirable. (2) Fear that risk (i.e. damage to desirable plants) is too great compared with chances of success.

Biological control with insects is not a short-term alternative but rather a long-term program that requires many years of research and development with the outcome never being highly predictable (Vallentine 1989). Biological control alone is seldom totally effective, but rather requires the use of supplemental control methods to additionally stress the target plant.

Although insects have received primary attention for biological control of weeds, other natural enemies with potential control value include fungi, bacteria, viruses, parasitic higher plants, plant mites, nematodes, and an assortment of other small or microscopic animals (Andres et al. 1976). Kennedy (1992) discussed effective use of bacteria to inhibit cheatgrass growth which resulted in greater wheat yields.

Biological control by insects has been successful to at least some degree on the following: pricklypear in Australia; St. Johnswort or Klamath weed (*Hypericum perforatum)* in California, Oregon, Washington, Idaho and Montana; Tansy ragwort *(Senecio jacobaea)* in California and Oregon; and on mesquite in Texas (Vallentine 1989). Current research in the United States and Canada is being directed against selected noxious plant species of grazing lands including: Canada thistle *(Cirsium arvense),* musk thistle *(Carduus mutans),* bull thistle *(Cirsium vulgare),* Russian thistle *(Salsola kali,* Russian knapweed *(Centaurea repens*), and related knapweeds including yellow star-thistle *(C. solstitialis),* halogeton *(Halogeton glomeratus),* hoary cress or whitetop *(Cardaria draba),* leafy spurge *(Euphorbia esula),* Dalmatian toadflax *(Linaria dalmatica),* saltcedar *(Tamarix pentandra),* and selected native species such as silverleaf nightshade *(Solanum elaeagnifolium)* and broom snakeweed *(Xanthocephalum sarothrae)* (DeLoach et al. 1986, Goeden et al. 1974, National Research Council 1968, Vallentine 1989).

D. Establishment Islands

Establishment of islands of desirable vegetation to serve as mechanisms for dispersal onto surrounding deteriorated rangelands has to our knowledge not been evaluated. Seed and mycorrhizal dispersal out from such islands may be an efficient and low risk method of reestablishing desirable vegetation on degraded rangelands. Spread of perennial grasses from established stands on sites to which they are adapted has been noted in the cases of crested wheatgrass (Marlette and Anderson 1986 citing Hull and Klomp 1966, 1967) and orchardgrass (D.E. Johnson, unpublished data), both introduced species. Marlette and Anderson (1986) noted little invasion by native perennial grasses into established crested wheatgrass stands. They suggested that one reason for sparse dispersal of propagules from the native community is apparent in the close correlation between the distribution of viable propagules and the distribution of parent plants. Most of the native species possess no specialized mechanism for long-range dispersal, and such plants generally show an exponential decrease in the number of seeds deposited as distance from the parent increases.

Spread of weeds from patches has been described. Mack (1981) described the spread of cheatgrass *(Bromus tectorum)* as being like a coalescing of “leopard spots” which rapidly covered the *Agropyron spicatum* Province between 1919 and 1930. All that was apparently required was unoccupied, suitable space. In a paper presented to BLM’s National Weed Evaluation Team in 1991, James A Young (USDA-ARS, Reno, NV), Bill Phillips (BLM, Susanville, CA Dist.) and Glen Nader (Cooperative Extension Service, U. of Calif.) provided a history of medusahead in the western Great Basin. During the 1970s there was a sudden surge in medusahead distribution, from small, scattered, infestations, when the Tablelands area northeast of Susanville was converted from low condition bluebunch wheatgrass/needlegrass/cheatgrass to dominance by medusahead. About 50,000 acres became dominated by medusahead in less than a decade. Moody and Mack (1988) simulated expansion from foci and concluded that small satellite foci present a greater expansion potential than a large central foci.

Efficacy of establishment islands of desirable native species needs to be evaluated. Seed and mycorrhizal dispersal, and establishment and survival patterns all need to be studied. Methods of facilitating dispersal and planting of desirable plant seed also need study.

IV. Plant Materials and Seed Technology

A. Ecotypic Adaptation vs. Phenotypic Plasticity

Hoekstra (1992) presents an evocative argument for use of locally adapted ecotypes when using native species for revegetation. His argument is essentially that ecosystems developed with such a diversity of genes and that ecotypes of the same species (assuming genetic differentiation) are not interchangeable in the same niche. Ecosystems are essentially custom-tailored, with the genetic makeup of individuals adjusted to fit the stress parameters of individual environmental niches. Hoekstra is concerned about inbreeding that may lead to genetic mediocrity. In the context of forests, he states ‘The evidence, however telltale, suggests that the genetic specifications of nature differ broadly from the ones we cultivate, and that we need to research the difference between the wild forests of evolution’s vintage and the domesticated ones we make.” (page 56).

Unfortunately, very little is known about genetic variability versus phenotypic plasticity in native species likely to be used in restoration of severely degraded Great Basin and Columbia -Snake River Plateau rangelands. Large phenotypic plasticity for a given species might allow use of seed produced from other locations. Large genetic variability would suggest the need to use local ecotypes in revegetation/restoration attempts. Research results suggest that for a number of species, genetic variability is a factor for seed germination characteristics, time of flowering, etc., but that a great deal of within-population variability also exists.

In a study of variation in germination response to temperature in rubber rabbitbrush, Meyer et al. (1989) were not able to clarify whether between-population differences in germination patterns represent ecotypic (genetic) differentiation or the response of a generalist genotype to environmental conditions during seed maturation. They referenced Naylor (1961) to suggest that date of floral bud initiation is probably under genetic control, which in turn strongly influences date of seed maturation and thus the environmental conditions under which the critical final states of seed maturation take place. Meyer et al. (1989) concluded that germination patterns of rubber rabbitbrush are probably not under rigid genetic control, but represent an integration of genetic and environmental factors.

According to Meyer et al. (1987), seed germination patterns are ultimately under genetic control if they can be explained in terms of their adaptive significance. They cite several studies which suggest that while the limits of variation of germination patterns are set genetically and are heritable, the influence of environmental factors during seed development on the mother plant is significant. Within-species variation in germination characteristics can be approached at several levels including: (1) differences among populations; (2) differences among plants in a population; (3) differences among seeds on an individual plant; and (4) differences among harvest dates or years of production (Meyer et al. 1987). Common gardens and outplantings used for evaluation of plant materials at the post-establishment stage could provide the necessary contrasts to study differences in what should be genetically similar materials ripened under contrasting conditions and of what may be genetically contrasting materials ripened under similar conditions.

Meyer et al. (1987) reviewed the literature for five shrub species relative to intraspecific variation with respect to seed germination. Studies have suggested that winterfat exhibits population differences in germination response to temperature and to osmotic stress. Within a population, year-to-year differences were found in both viability loss through time and rate of afterripening. The possibility of between-population differences was suggested for four-wing saltbush, but conclusive evidence was lacking. Source differences in antelope bitterbrush seed germination was also suggested but the absence of clear patterns was noted. As noted above (Meyer et al. 1989), seeds of rubber rabbitbrush from different habitat types did respond differently to temperature. Work by the authors at the time of publication was suggesting source differences in seed germination for big sagebrush both among and within subspecies. Meyer and Monsen (1990) have concluded that even though site- and year-specific weather events have an overriding effect on the probability of successful establishment for rubber rabbitbrush and big sagebrush, use of seedlots collected at similar sites increases the probability of successful establishment.

In a series of papers, Rice and Mack (1991 a,b,c) discussed the tremendous phenotypic plasticity of cheatgrass *(Bromus tectorum).* They suggested that fitness within field populations of cheatgrass may be largely environmentally determined. Genotypic similarity between large and small individuals in natural plant populations and the prevalence of “safe sites” suggest that microenvironmental variation in resources often overrides genetic differences in determining plant fitness. Lack of density-dependent mortality in annual plant populations (in species such as cheatgrass) at high density may be important in preserving within-population genetic variability. Thus for most traits, ecotypic differentiation is not much of a factor. However, an ecotypic response, time to flowering, by cheatgrass was significant. Also, in terms of net reproductive rate, evidence for local adaptation in cheatgrass was obtained in populations from habitats representing environmental extremes. Thus, even with a great deal of phenotypic plasticity, cheatgrass does exhibit ecotypic variability for some traits.

Clary (1975) studied potential ecotypic adaptation in squirreltail *(Sitanion hystrix*). Relative phenological development could be predicted by a climatic scale representing temperature and moisture conditions at the original collection sites. Plant size and dry matter production could not be predicted as reliably, suggesting that the primary factors which influence morphological and production characteristics may be more numerous or complex than those which influence phenology. In a related paper, Clary (1979) stated that ecotypic responses to climate are often through variation in phenology and dry matter production, whereas responses to grazing are often variation in growth forms and phenology. Responses to edaphic variation may be physiological rather than morphological or phenological. Citing several references, Clary (1979) observed that ecotypic differences in grasses have been shown to occur in numbers of vascular bundles, in stomatal density, and in numbers of mesophyll cells. Other references were cited to note epidermal variations, and photosynthetic and respiration rate variations within species. Clary (1979) noted, however, that for grasses, it appears that most within-species variation in internal structure and photosynthesis has been demonstrated among genotypes developed in plant-breeding programs, rather than among naturally occurring races.

We need more information about the roles of ecotypic variation and phenotypic plasticity of plant species used in revegetation/restoration of Great Basin and Columbia Plateau rangelands.

Native Plant Breeding and Evaluations of Accessions/Cultivars

USDA-ARS Research Geneticist Tom Jones (Forage and Range Research Laboratory, Logan, Utah) is pursuing a native grass breeding, germplasm collection, evaluation, and improvement program. Species are identified that are potentially important for revegetation efforts, but are specifically limited by a feature which can likely be ameliorated by plant breeding (e.g. seed dormancy, awned seeds, first year growth rate). Some of these problems can be approached by hybridization with a closely related taxon. Germplasm is collected from native sites and evaluated in small-plot trials. Selection is practiced on promising naturally occurring populations and on polycross populations generated by hybridization between individuals of the identified populations. Taxa of interest currently are: bluebunch wheatgrass (*Pseudoroegneria spicata*), Snake River wheatgrass *(Elymus lanceolatus* ssp. *wawawaiensis),* thickspike wheatgrass *(E. lanceolatus* ssp. *lanceolatus),* indian ricegrass *(Oryzopsis hymenoides*), basin wildrye *(Leymus cinereus*), and beardless wildrye (*L. triticoides).* In his 1991 annual report, Jones stated that germplasm holdings for some species are adequate, but collections for others remain meager. Much collected germplasm remains unevaluated. Nearly all released cultivars of these species are populations identified as superior in evaluations, but unimproved by artificial selection.

Breeding programs such as Jones' may provide materials for restoration of degraded systems with little or no native seed source remaining. Hoekstra's (1992) admonition to beware of breeding in mediocrity needs to be remembered, especially if a native seed source is available to be expanded and ecotypic variation is known or suspected.

Some native plant materials are currently being evaluated by the Soil Conservation Service (SCS) and the U.S. Forest Service (USFS) for the BLM's Intermountain Greenstripping and Rangeland Rehabilitation Project. The Aberdeen Plant Materials Center of the SCS is conducting inter-center strain trials, some Greenstrip plots, a display nursery and a row-spacing trial at the Orchard Advanced Testing Sites near Boise, ID of native accessions and cultivars including thickspike wheatgrasses (including Snake River wheatgrass), bluebunch wheatgrasses, basin and altai wildrye, Indian ricegrass, fourwing saltbush, and winterfat. Preliminary results indicate that some species show excellent success even under drought conditions (progress reports submitted to IGRRP, BLM, Boise, Idaho).

The USFS Shrub Sciences Laboratory has been conducting evaluations of accessions and cultivars of bluebunch wheatgrass, thickspike wheatgrass, Lewis flax, western yarrow, silver sagebrush, and fourwing saltbush. Studies concerning the germination, seedling vigor, adaptability, burning tolerance, competition with exotic annuals, and genetic manipulations are being conducted with some or all of these species. New collections were made of accessions of bitterbrush, Thurber's needlegrass, bottlebrush squirreltail, Sandberg's bluegrass, and Minidoka penstemon (progress reports submitted to IGRRP, BLM, Boise, Idaho).

B. Seed Treatment

Plant parts dispersed with the seed sometimes have mechanical and/or chemical functions that contribute directly to germination success. Besides the commonly recognized function of seed dispersal, seed coverings and appendages may interact with the seed's environment by affecting seed positioning, seed fixation (anchoring), hydraulic conductivity, seed protection, substance transfer to the embryo, and regulation of seed respiration. The natural operation of each of these functions should be considered before sowing (or modifying for sowing) diaspores of rangeland plants (Booth 1987).

Indian ricegrass and winterfat have been studied extensively with respect to germination characteristics and to treatment of seed to enhance germination. Summaries of seed treatments for these species are provided in Appendix E. Similar information is needed on other native species with potential for use in restoration of degraded rangelands to reduce the risk of failed seedings.

Jones (1990) has recommended an interdisciplinary approach including seed physiology, seedbed ecology, seed technology, and plant breeding in an attempt to solve the problems of Indian ricegrass dormancy, seed production, and seedbed management practices for various soils and to enhance establishment success. He suggested that the potential of seeding Indian ricegrass for improving rangelands can only be realized after low dormancy seed becomes available, appropriate seedbed management practices are developed, and seed shattering losses are reduced. Some of these problems likely afflict other native species. A similar recommendation might be appropriate for those which exhibit dormancy, erratic and/or extended germination, or other related problems with respect to achieving an established stand.

C. Seeding Techniques

Planting depth, rate, time, and related information for several of the Vegetation Diversity Project priority species is provided by Wasser (1982) and is listed in Appendix B.

Restoration of degraded sites to native species with a degree of plant diversity will require a mixture of species. Most range seedings have involved single species or simple mixtures rather than complex mixtures. Wildlife and reclamation seedings are possible exceptions (Vallentine 1989). BLM's Intermountain Greenstripping and Rangeland Rehabilitation Project (IGRRP) is currently using seed mixes of five to nine species, including both native and introduced grass, forb, and shrub species. Seeding of mixtures has generally involved either broadcast seeding or seeding each species in alternate rows when drill seeding. Additional work is needed to develop and/or evaluate methods for seeding species mixtures on different sites and to incorporate clumped seed and plant distributions. Collaboration between the Vegetation Diversity Project and IGRRP (Pellant 1990), which is administered from BLM's Idaho State Office, should provide an efficient use of limited resources to approach this research need.

Booth (1987) discussed current technologies for sowing 'problem' diaspores. Diaspores are seed, fruits, fruits with attached structures, or even flowerheads or whole aerial plants with several to many seeds dispersed as a reproductive unit. Diaspore forms and functions vary by species. The retention of these appendages is important in assisting natural seed distribution and germination. Therefore, on many species, we do not want to use breeding techniques that would eliminate these structures. Management (i.e. presowing treatments and methods of sowing) should reflect the variation and the specific adaptations of each plant. Diaspore management may mean threshing seeds from their coverings to promote germination; or implementing new technology, such as fluid drilling, to sow intact diaspores thus using the growth promoting relationship between seed and appendages. Diaspores that are fluffy, hairy, awned or otherwise incompatible with standard drills, or that are adapted to surface germination and require assisted fixation to keep the seed in place, pose special problems in mechanized sowing. Much of the following discussion is from Booth (1987).

Special Drills

Seed drills were developed to plant slick seed. Other kinds of diaspores, especially those with appendages, may jam or bridge the drop holes in standard seed drills (Pellant and Reichert 1984). The development of metering devices that can handle fluffy seed, and their incorporation into commercial drills (Wiedemann and Cross 1981; Wiedemann 1982) has greatly improved this situation. These drills provide the capability to uniformly disperse appendaged seed and to place it in the soil at an appropriate depth, or broadcast it on the surface for seed adapted to surface germination.

Broadcasting

The practice of broadcast sowing has increased with passage of reclamation laws requiring species diversity and with the emphasis on native plants. In some cases broadcasting has been the only practical method, either because of the terrain or because of "trashy seed" (Ries and DePuit 1984). DePuit and Coenenberg (1979) found broadcasting small seeds was better than drilling them 2.5 cm into the soil. However, as a means for sowing seeds adapted to burial, broadcasting is, at best, inefficient relative to established plants from sown seed (Wood et al. 1982, Herbel 1986). Broadcasting does not fix seeds in one location. Seeds may be removed from the sown area by secondary dispersal (Parady 1985) and/or plant establishment reduced because fewer radicles penetrate the soil surface. Seedbed treatments that disturb the soil surface before or after broadcasting do increase the number of fixed seeds and often give satisfactory results (Luke and Monsen 1984, Herbel 1986). Successful germination and establishment of broadcast seed may be enhanced by: (1) surface modifications, to better accommodate creeping and lodging diaspores; (2) use of fluid and solid carriers to enhance fixation of broadcast units; and (3) timing, to use impending precipitation events or saturated seedbeds to increase the number of diaspore appendages that become embedded in the soil.

Snowbankseeding

Some work has been done with sowing through or onto accumulated snow. Winterfat diaspores dropped onto the soil surface through 4 cm diameter holes punched in 30 to 60 cm of snow established 25% of the pure live seed (PLS) sown (Booth 1987). The bottom of a snowbank is a protected site where fixation readily occurs and moisture is not limiting; however, without mechanized equipment the method is labor intensive and slow. Another method is to broadcast seed over a thin snow cover, 5 - 10 cm (2 - 5 in), on a sunny day to allow the seed to melt through the snow to the soil surface. This will ensure both escape from birds and initial moisture for imbibition.

Pelleting

Pelleting of hairy or fluffy diaspores reduces clinging and it makes mechanical dispersal easier and more uniform. Properly functioning pellets anchor the diaspore in place as the pellet dissolves. Kocher and Stubbendieck (1986) showed that pelleting did not reduce seedling establishment. If pelleting is used diaspores should be pelleted as close as possible to the planting date to avoid breakdown of pellets during storage.

The use of hydrophilic pellets has been proposed as a method of attracting water to the seed and thus enhancing germination, but this has been shown to be unsuccessful. Hydrophilic pellets did not increase the germination or emergence of *Elymus junceus* (Berdahl and Barker 1980). Various other methods of seed pelleting and coating have been tried with range grasses adapted to burial, and have not been successful (Hull 1959, Vallentine 1989). Pelleted seed requires a prepared seedbed equally as much as nonpelleted seed (Chadwick et al. 1969). Poor germination and establishment have resulted from broadcasting of pelleted seed by airplane or by hand, and this limitation has not been overcome by increased seeding rates (Bleak and Hull 1958, Hull 1959). In addition to sparser stands, the cost of the pelleting and the extra cost of handling the extra bulk have been high (Chadwick et al. 1969). Some pelleting processes have greatly reduced seed germination (Vallentine 1989).

According to Vallentine (1989) various substances such as mud, fertilizer, and plastics have been used in making three basic types of seed pellets: (1) coated pellets in which individual seeds receive successive layers of powdered material; (2) extruded pellets made by pressing a pasty seed and soil mixture through holes; and (3) compressed pellets made by running a seed and soil mixture through pressure disks (Hull 1959). No pelleting process has shown consistent advantages over using nonpelleted seed on rangelands, and the practice of using pelleted seed has been virtually discontinued. The Bureau of Land Management's (BLM) Greenstripping Project has evaluated pelleting recently and has judged the method successful with regard to mechanical distribution of the diaspores (Mike Pellant, personal communication). However, the cost of having seed pelleted was becoming prohibitive. Seed coating of fluffy or trashy seed to obtain more accurate seed placement and better seed mixing when using conventional seeding equipment shows some promise (Vallentine 1989).

Hydroseeding

Pellant and Reichert (1984) have reported the use of a hydroseeder to sow winter-fat diaspores with a mixture of grass seed. Hydroseeding overcame problems of bridging and seed separation encountered with other machines, and it allowed the operator to select good microsites, as opposed to uniformly sowing all landscape surfaces. Diaspore distribution was uniform within planted areas. The method was labor intensive and required large quantities of water to be hauled to the field site.

Fluid Drilling (Gel Seeding)

The suspension of diaspores in a hydrocolloidal gel overcomes the problem of synaptospermy (i.e. seeds which are not dispersed but germinate alongside the parent) while fixing diaspores to the soil surface in a manner similar to natural mucilage (Booth 1985). Unlike pelleting, mixing diaspores into a gel is not time consuming nor does it require highly specialized equipment. Planting equipment is commercially available or can be fabricated (Ghate et al. 1981 Booth and Griffith 1986).

Fluid drilling does not damage soft seeds and can be used to sow preimbibed and pregerminated diaspores. This is especially important for those species where water uptake is restricted by seed coverings or where natural stratification is a problem (Booth 1985). Apparent advantages of sowing pregerminated diaspores of rangeland plants is greatly complicated by wide germination spans inherent in seedlots of many wildland species. However, osmotic pretreatment may synchronize germination of some of these species (Bradford 1986, Morgan and Booth 1987).

In his summary, Booth (1987) stated that good seeding management requires: (1) an understanding of the mysteries of specific seedbed ecologies; and (2) innovation in adapting methods of seed distribution and fixation that will complement, rather than contradict, those diaspore functions most critical to seed success.

D. Legume Inoculation

Vallentine (1989) discussed legume inoculation with *Rhizobium* bacteria. The successful establishment and production of legumes in range and pasture seedings depends on effective nodulation and nitrogen fixation. Since *Rhizobium* remains near the infected plant it is important that inoculated individuals are distributed well across the landscape (Lowther et al. 1987a,b). Legume seed should be treated with a good commercial inoculant prepared from a strain of *Rhizobium* bacteria specific for the legume being planted.

Mixing of inoculant and seed can easily be accomplished by mixing in a cement mixer or dry feed blender or in a can with a closed lid. Legume seed previously inoculated is now generally available for purchase. When properly inoculated, legumes add nitrogen to the soil and can materially reduce the amount and cost of nitrogen fertilization. Under California dryland conditions, range legumes effectively nodulated were found to fix at least 52 pounds of nitrogen per acre in one growing season (Holland et al. 1969).

E. Mycorrhizal Fungi Inoculation

Mycorrhizal associations are present in most plant species on semiarid lands. Within individual root systems, the abundance of mycorrhizal colonization will vary seasonally. In *Artemisia tridentata,* colonization appears to increase from a low of 47% in April to a high of 80% in May. Soils in the shrub-steppe habitat in southwestern Idaho tend to be low in organic matter, low in available P and N, and have limited available water. The ecological importance of mycorrhizae in this habitat appears to be related to their role in acquisition of nutrients. Following disturbance, these lands are normally invaded by either nonmycorrhizal or facultative mycorrhizal plant species, such as cheatgrass. Plants colonizing the site the first year following a fire do not form mycorrhizal root infections. Studies on revegetation of severely disturbed land indicate that the presence of mycorrhizae improves survival and growth of host plant species (Wicklow-Howard, pers. comm.).

Wind and water are thought to be the main means of dispersal for fungal spores in rangelands (Allen et al. 1989). A variety of mammals may be locally important in dispersing spores of mycorrhizal fungi on rangelands of central and eastern Oregon (Allen et al. 1992, Maser et al. 1988).

Waaland and Allen (1987) conducted a study to evaluate the relationships between vesicular-arbuscular mycorrhizal (VAM) fungi and plant cover following surface mining in Wyoming. They evaluated the relationship of VAM to succession by dividing the plants into functional groups. The early successional species were predominantly annual members of the Chenopodiaceae and Brassicaceae, which do not form mycorrhizal associations (Pendleton and Smith 1983). *Agropyron* species on site were mid to late seral and formed moderate levels of infection. Shrubs tended to have greater infection than co-occurring grasses with the exception of four-wing saltbush *(Atriplex canescens).*

Little appears to be known about VAM inoculation requirements for restoration efforts of degraded rangelands which are dominated by annual grasses and forbs. VAM is probably not present or viable and inoculation of transplants or topsoil would probably aid in establishment of desired native plant species. VAM indigenous to the area are probably needed (Wicklow-Howard, personal communication), or staggering the introduction of species so that facultative mycorrhizae associated plants are established first, then introduction of more obligate species is delayed until VAM is present on the site (Allen and Allen, in press).

See also discussion of VAM in Sagebrush-Steppe portion of Ecosystem Descriptions.

V. Maintenance of Native Plant Diversity

A. Demography

The ability to maintain desired plant communities is critical to long-term success of sustained multiple-use of BLM lands. Current land-use practices include livestock grazing, wildlife habitat management, mineral exploration, and recreation. Traditional rangeland management evaluates the impact of use through several means (e.g., rangeland trend, key-plants or areas, utilization). With the exception of rangeland trend measurements, these techniques tend to specifically examine the forage species (Holechek et al. 1989) and ignore species that contribute only a small part of the total biomass or cover for the site. Measured trend evaluates a combination of plant and soil parameters for a specific area over the course of time, and, if all species are included, may provide a method for monitoring trend in plant diversity for a site under a given management regime. Trend measurements, however, do not provide detailed demographic information (e.g., birth, death, survival, life expectancy, sources of mortality) that is necessary for predicting responses of plant populations to disturbances or to climatic changes.

We have very few data sets on the life expectancy of most of the dominant perennial plants of the Great Basin and Columbia-Snake River Plateau. Exceptions include a few analyses of some pantograph studies initiated during the mid-1900s at experiment stations in Utah and Idaho. These include studies of three-tip sagebrush *(Artemisia* tripartita), bluebunch wheatgrass, Indian ricegrass and needle-and-thread (Stipa comata) in Idaho (West et al. 1979), and of shadscale, winterfat and budsage in Utah (Norton 1978, Harper et al. 1990). Some information on life expectancy can be gained using ring counts of woody plants such as sagebrush (Ferguson 1964), however, ring counts of many woody species in salt-desert shrublands are unreliable because of production of false rings.

Long-term demographic monitoring plots need to be established in conjunction with climatic monitoring. These plots would detect climatic conditions necessary for successful establishment and maintenance of native perennials, including rare plant species, and would provide a demographic baseline that could be used for incorporating demographic information into rangeland trend measurements (Gardiner and Norton 1983, Owens et al. 1985).

B. Herbivory

Some research indicates that moderate grazing by livestock will result in a reduction in herbage production over that of ungrazed reference areas (Lacey and Van Poollen 1981 report 68 $\pm$ 22 % reduction, n = 20 sites), but to our knowledge these studies are almost exclusively concerned with grasses and shrubs and tend to ignore the forb component (e.g., Anderson and Holte 1981). It is clear that protection from grazing alone will not guarantee an improvement in species diversity (a - diversity, a combination of species richness and abundance) because release from herbivory normally results in an adjustment in dominance of the current community (Rice and Westoby 1978, Smeins et al. 1976). There is a need for research to identify seasons of use and levels of use that will maintain all life forms (shrubs, perennial grasses, and forbs) and will provide information on species likely to be susceptible to herbivory.

Recent results on the effect of spring grazing on bluebunch wheatgrass indicate that grazing during the period of apical meristem elevation (late-April through May or June depending on the year) can severely reduce the ability of this grass to activate lateral buds for tiller replacement in subsequent years (Mueller and Richards 1986, Richards et al. 1988, Busso et al. 1989, Busso et al. 1990). Many native grasses may respond similarly to grazing, but experimental evidence is not available. Shrub tolerance to browsing is closely related to location and viability of buds necessary for regrowth. Browsing intolerant shrubs often have buds for regrowth located on branches that are highly susceptible to browsers, whereas tolerant shrubs have viable buds for regrowth located throughout their canopies (Bilbrough and Richards 1991). Little is known concerning responses of native forbs to herbivory

C. Fire

The wildfire management strategy of the BLM, as with most federal land management agencies, has been to control wildfires as soon as possible. This has potentially contributed to an increase in fire sensitive shrubs. Long-term data sets indicate that even without grazing, increases in sagebrush coverage can be anticipated when fire is controlled (Anderson and Holte 1981, West 1983b). With periodic fires, grasses become dominant and in some areas forbs can increase (Daubenmire 1975, Harniss and Murray 1973). Season of burning is critical to achieving successful results following fires. Prescribed burning of sagebrush stands between 30 and 60 years old may be useful in stimulating a natural cycle without the detrimental effects (e.g., mortality of perennial grasses and increases of exotic annuals) of summer wildfires (Britton and Ralphs 1979, Wright et al. 1979, Bunting et al. 1987). Controlled burning needs to be investigated as a means of regulating shrub dominance and of enhancing species diversity in sagebrush ecosystems.

D. Climate

Climate strongly influences not only herbage production, but also survivorship of some perennial grasses (Chamrad and Box 1965, Herbel et al. 1972) or can result in shifts in dominance when season of peak precipitation shifts (Pieper and Donart 1973 cited in Holechek et al. 1989). Models that predict the ecosystern responses to various global climate change scenarios indicate that elevated levels of CO_2 and changes in precipitation pattern are the variables that account for most of the variation in biotic responses (Hunt et al. 1991). A predicted doubling of the current atmospheric CO_2 concentrations to approximately 600 uL/L by 2050 may cause changes in primary production (Long and Hutchin 1991) and changes in the dominant species. Higher CO_2 concentrations may favor exotic annuals over native perennials (Smith et al. 1987). Studies of previous changes in climate indicate that adjustments in plant dominance among communities have lagged behind climate changes by hundreds of years (Cole 1985, Shugart et al. 1986).

Research needs to focus on demographic and physiological responses of native and exotic species that currently coexist in Great Basin and Columbia Plateau plant communities under several climate change scenarios (elevated CO_2 changes in precipitation amounts and seasons). Such experiments would help managers in monitoring for early indications of the impacts of climate change and in making knowledgeable management decisions should climate change occur. This research must not be restricted to vascular plants, but must include other parameters that may feedback to the primary producers, such as fluxes in soil nutrients and abundances of soil microbes associated with mineral cycling (Hunt et al. 1987, Perry et al. 1990). These studies will require long-term field experiments (at least 5 years) to determine if semiarid plants will eventually adjust to elevated levels of CO_2 like some arctic species (Riechens et al. 1987).

VI. Special Status Plants

Along with maintaining the dominant species that constitute a plant community, managers need to understand the life histories of the rarer components to effectively manage them as well. Special status plants are those species recognized by either state or federal government as having few known extant populations and as being potentially threatened with extinction. Species are placed in this category if they meet one of the following criteria: (1) they are a proposed or listed threatened or endangered species under the U.S. Endangered Species Act or by a similar state regulation (federal or state listed or proposed species); or (2) they are suspected to be threatened or endangered, but require further information for the species to be proposed for federal or state listing (federal or state candidate species).

Management for maintenance of special status species requires a thorough understanding of the criteria for maintaining a viable population. Information on expected survival time, life history characteristics including seedbank characteristics, and on the effect of environmental variation on these factors is required to determine if populations of special status species will remain viable (Goodman 1987). Ideally, we would like to determine the minimum viable population for all special status plants, but this is not economically possible.

Occasionally, management practices intended to control pests like insect infestations or noxious weeds may have detrimental impacts on species other than the target species. Insecticide spraying to control grasshoppers and crickets may also kill specialist pollinators of rare plants. Use of broad-spectrum herbicides to control noxious weeds may place the survival of coexisting plants in jeopardy. If susceptible pollinators or plants were known before treatments began, then alternative management treatments could be used.

It may be useful to utilize those special status species for which some life history information is available in demonstration studies that adjust management to favor their maintenance or spread. An example is *Happlopappus radiatus* which currently coexists with cheatgrass on degraded rangelands and which is suspected of being grazing sensitive. Cheatgrass appears to competitively restrict seedling establishment of this special status species. Studies could be initiated to examine the impact of removing grazing on the growth, reproduction, and survival of *Happlopappus radiatus.*

Another approach might be to concentrate efforts on restoration of special status species on sites where they once existed or potentially existed. Examples include restoration of *Allium aaseae* on sites in Idaho or of *Polemonium pectinatum* along drainages in eastern Washington. These species are susceptible to surface mining disturbances and to weed control with herbicides, respectively, but show the potential for restoration.

A third approach is to compare the life history characteristics of several special status species within a common genus. The objective of these studies would be a determination of common characteristics of these special status species. Several genera have multiple special status species located throughout Idaho, Nevada, Oregon, Utah and Washington. Examples include *Astragalus, Eriogonum,* or *Penstemon.* Few studies have taken this approach. An exception is a pair of studies comparing breeding systems between rare and common *Astragalus* (Karron 1987, 1989).

A final approach is a study of common characteristics contributing to the rarity of species with similar growth forms. Growth forms might include annuals, bulb forming perennials, rhizomatous perennials, and nonclonal perennials.

VII. Concerns of Land and Resource Managers

Dr. David Pyke (Senior Rangeland Ecologist, Vegetation Diversity Project), Dr. Michael Borman (Rangeland Ecologist, Vegetation Diversity Project), and Jerry Asher (Research Coordinator, Oregon State Office) visited BLM state offices in Idaho, Nevada, Oregon, and Utah, and BLM district offices in Burns, Lakeview, Prineville, Spokane, and Vale during February through April 1992. These visits were intended to allow the research scientists and the personnel in state and district offices to become acquainted and to allow state and district personnel direct input about issues and concerns they would like to have addressed by the Vegetation Diversity Project. Input varied across both states and districts as a function of differences in resource management needs included within each jurisdiction. However, there were many common issues and concerns voiced among the various states and districts. A brief synopsis of the results of these meetings is provided here. Specific comments from each state and district visited are provided in Appendix G.

With the exception of Utah, the Wyoming big sagebrush community type was considered to be the number one priority for research needs for both reestablishment and maintenance of native plant communities. The Salt Desert Shrub community was number one in Utah and second in priority for Nevada and for the Burns, Lakeview, and Vale Districts in Oregon.

Within Wyoming big sagebrush communities, the conditions most commonly described as problems requiring attention were: (1) extensive areas with excessive sagebrush canopy coverage and very little understory; (2) extensive areas of annual grass domination with sagebrush and other components effectively absent; and (3) areas of exotic weed encroachment, particularly by medusahead rye and the knapweeds.

Basic information that managers generally desired the Vegetation Diversity Project to eventually provide included: (1) techniques to successfully establish desirable native plants; (2) information about the plants which may be useful in restoration projects, especially noted was a lack of information about forbs; (3) management for maintenance of newly established and of existing desirable native plant communities; and (4) methods of preventing, or at least slowing, encroachment and subsequent spread of noxious weedy species.

Technology Transfer

The intent of the Vegetation Diversity Project is to plan and implement research and demonstration programs which will provide new information and technology for restoration/reclamation of those deteriorated rangelands in the Great Basin and Columbia Plateau on which livestock management alone is not expected to make significant improvements in the vegetation condition in a reasonable time frame. The present knowledge base is not adequate to design a management plan for restoration and maintenance of native plants on this diverse area. For the BLM to accomplish its objectives of maintaining vegetation condition where it is currently acceptable and to restore desired vegetation where lands have been degraded, information learned through the VDP must be transferred to BLM land and resource managers and employees, livestock operators, and other interested parties. Such information must also be provided to academia; other federal, state, and local agencies; professional societies; Congress; other BLM employees; and the general public. Technology transfer programs may include, but are not limited to, the following:

- A quarterly newsletter to provide (1) updated information on VDP activities; (2) information from District level projects and programs relating to the VDP of potential interest to other Districts and interested parties; and (3) pertinent literature, conferences, professional meetings, etc.

- Annual meetings will be held to evaluate research project progress, results, and future projections. Research scientists, graduate students, and appropriate BLM personnel will participate.

- Develop workshops for District personnel which present management (application) implications of research results. Workshops will be incorporated into field days as appropriate.

- Field Days at research/demonstration sites will be conducted independently or in conjunction with university Extension Service programs. When possible, field days and research application workshops noted immediately above will be integrated.

- Poster displays will be developed featuring VDP studies and programs for presentation at conferences, field days, state and county fairs, and professional meetings.

- Annual and final research reports and demonstration findings will be published and distributed to appropriate audiences.

- Videos, classroom lectures, presentations to other interested parties, pamphlets, and special in-house bulletins will be prepared and presented/distributed.

- Research results will be expected to be submitted for publication in refereed scientific journals within the first 12 months after the completion date of a study.

- Rangelands, and other similar publications, will be utilized to publish interesting research and demonstration information not suitable for more scientific publications and/or to provide nontechnical discussions of research and demonstration results.

- BLM public affairs efforts will be utilized to provide public outlets.

- Expert Systems will be evaluated, used, and/or developed as sufficient information becomes available to help develop management programs for reseeding, prescribed fire, grazing management, etc. As an example, an expert system for prescribed burning on rangelands is being developed by Wright et al. (1992). The system is described in Rangelands vol 14, October 1992. It is being evaluated by users outside west Texas for use in other systems. We will attempt to either obtain a license to evaluate it concurrently with others or to at least interact with those evaluating the system to determine its potential to provide a useful tool for BLM and others in the Great Basin and Columbia-Snake River Plateau regions.

An Expert System of the sort we are likely to use or develop is essentially a knowledge based approach to solving problems or making decisions. A computer program emulates the problem solving strategies of a human expert. By its nature, an expert system is knowledge intensive. To achieve a satisfactory level of performance, it requires a “knowledge engineer” to work very closely with an expert to identify and describe how the expert makes decisions. Most expert systems are written using production rules to capture decision knowledge (i.e. if-then rules). Production rules capture heuristic (rule-of-thumb) knowledge. An expert system must be evaluated against the expert it attempts to emulate. If several individuals are considered to be experts and we desire to capture the expertise of each in an expert system, then an individual expert system, or at least individual modules within a given system, must be developed for each. In that way, individual decision making processes could be addressed for a given problem.

Research and Demonstration Tasks

The proposed studies presented below are not designed to be detailed study plans, but to provide guidance in prioritizing the various aspects of this project. The studies are written in a general fashion so that projects could be conducted within any of the communities listed below, but recognizing the priorities given to each community type. We have attempted to provide specific objectives for each study and to prioritize each study by placing the study under one of three priority levels (P1 being high and P3 being low priority studies).

We recognize there are many ways that these objectives might be addressed. In some cases we have suggested a general design with recommended levels or ranges for replications. The prioritized list of studies will be used as a guide in preparing requests for proposals, in selecting, and in funding studies during the duration of this project.

I. Plant Communities for Study

The selection of communities for study will intentionally be limited to upland shrub-steppe communities. Riparian communities and Pinion-Juniper communities will fall outside the scope of this project because the needs and concerns within these types of communities differ from those of the upland shrub-steppe and are either currently addressed under another project or are being reviewed for research needs under a separate problem analysis.

A. PI - Wyoming Big Sagebrush

The ecosystem that is the highest priority for study is the Wyoming big sagebrush system. It received the highest priority for three reasons: (1) it is the largest ecosystem on BLM lands in Nevada, Idaho, and Oregon/Washington and it is an important ecosystem in northeastern California and Utah; (2) the unpredictable and low level of precipitation have made standard revegetation practices only marginally successful; and (3) it is historically more susceptible than other ecosystems in the Great Basin to invasions by exotic annuals plants that reduce the species diversity of these sites (Sparks et al. 1990).

Three to four communities (e.g., habitat types, range sites, stable states) within this ecosystem should be selected for specific studies. These communities (listed from highest to lowest) should include bluebunch wheatgrass (*Pseudoroegneria spicata*), Thurber's needlegrass *(Stipa thurberiana),* needle-and-thread (*S. comata*), and Indian ricegrass *(Oryzopsis hymenoides)* and should focus mainly on low precipitation zones (8-10 inch) for competition and restoration studies. Study sites should be selected such that all replicates of a study are in the same plant association. If the sites have been disturbed, then replicated sites should maintain similar species compositions and soil types among replicates to ensure that the current communities are in similar stable states.

B. P2 - Shadscale

Shadscale *(Atriplex confertifolia)* ecosystems within the salt desert shrub will be given the second highest priority. This ecosystem is of major importance to Utah and Nevada and is a minor component in Idaho and Oregon. Several plant associations within this ecosystem are reported to be widespread, thus worthy of study. A prioritized listing includes associations with (1) Indian ricegrass *(Oryzopsis hymenoides), (2)* galleta (*Hilaria jamesii*) (3) winterfat *(Eurotia lanata),* (4) giant wildrye *(Elymus cinereus),* and (5) Sandberg's bluegrass (*Poa sandbergii).* Studies describing the successional transitions and states within this ecosystem are needed initially to provide an adequate background for the need of rehabilitation intervention or for changes in management to allow transitions to states of greater vegetation diversity.

C. P3 - Low and Black Sagebrush

Low sagebrush *(Artemisia arbuscula*) and black sagebrush (*A. nova)* ecosystems are lowest priority for study under this project. The reason for their inclusion are two-fold: (1) many of the plant associations in this ecosystem are similar to Wyoming big sagebrush communities, thus the successful principles for maintaining or enhancing diversity in the Wyoming big sagebrush communities should be tested for their applicability to similar low and black sagebrush communities; and (2) low and black sagebrush communities are interspersed throughout Idaho, Nevada, and Oregon, however, this ecosystem is of lesser importance to Utah.

II. Long-term Monitoring of Biological Diversity

Restoration of vegetation diversity on deteriorated BLM administered rangelands carries with it the necessity of understanding the natural diversity as it should be or is desired to be (Dr. Lee Eddleman, personal communication). The objective of restoring natural diversity to degraded rangelands requires first an idea of what natural diversity should be and secondly what are the differences between the desired communities and deteriorated communities. Also, since vegetative communities are dynamic in response to a dynamic environment over space and time, long-term monitoring of relatively intact (near 'pristine') sites and of similar ecological sites, but in deteriorated condition, will provide critical information necessary to realistically adjust management goals and objectives based on dynamics of climate and community responses. This information will also serve as the basis to evaluate results of other proposed studies.

Biological diversity must be measured at different levels of a hierarchy. Starting from coarser and proceeding to finer scales these levels include: (1) community diversity among watersheds or landscapes (e.g., across a BLM District); (2) species and structural diversity within communities; (3) genetic diversity within populations. These measures of diversity need to be made along a latitudinal, elevational, and disturbance (e.g., within communities of different stable states) gradient.

A. Diversity Across the Great Basin

1. **P1 · Evaluating Diversity Along Vegetation Transects: Monitor climatic conditions, edaphic condition, plant species richness, production, composition and structural diversity of vegetation along a latitudinal and successional vegetation transect with and without livestock grazing.**

A series of three to five watersheds should be located along a north-south gradient from Washington or Oregon into Nevada. All watersheds should have similar soil conditions and consist of a series of communities such that transects within each watershed could cross elevational ecotones associated with the current upper and lower limits of sagebrush communities, Replicated pairs of undisturbed (near pristine) and disturbed (degraded) communities would be located within each watershed. The pairs of communities should represent different stable states. If feasible, each community should have at least one, preferably two or more, 1-ha livestock exclosures constructed to provide grazed and ungrazed comparisons.

A series of permanent plots should be established to sample vegetation canopy coverage and production of all species of vascular and non-vascular plants. No one method is adequate for measuring all plant species, therefore several permanent-plot methods will be needed. A protocol that identifies the appropriate method for each species must be developed prior to the first year's measurements. Plots will be measured at least twice a year. Once in middle to late spring to monitor early season forbs, grasses, ephemeral annuals and non-vascular, late-season plants and once in early to middle summer (end of the growing season) for perennial grasses, forbs, and shrubs.

A general description will be made of the edaphic conditions of sites along the transect. Measure of organic matter, N, P, K, and depth of top soil would allow for comparisons among sites.

One climate station should be established at each of the selected watersheds. These stations should monitor daily temperature, precipitation, and soil moisture at three depths, 5, 15, and 25 cm. If possible stations should be located so that soil moisture measurements could be made in both undisturbed and disturbed communities. If this is not possible the daily soil moisture measurements should be conducted on undisturbed sites and separate measurements gathered on disturbed sites during site visits.

Summarized results of these studies will be provided semi-annually to the BLM's Global Change Research Program Data Center (GCRPDC).

2. **P2 · Data-base of existing diversity: From existing sources (e.g. Ecological Site Inventories, Natural Heritage Programs, etc.), develop a data-base of community types and unique species currently existing in the Great Basin and Columbia-Snake River Plateau regions.**

A data-base would be developed from existing Ecological Site Inventories (ESI) and from information in the various states' Natural Heritage Programs to identify community types and unique species within the community types on BLM lands in the Great Basin and Columbia-Snake River Plateau regions. This information would provide a partial baseline for identifying current diversity across these regions. This data-base would help answer the following questions: (1) What community types exist? (2) What unique species do they harbor? (3) What critical role do they play (if any) in maintaining regional biodiversity? (4) Are any of the community types so rare as to be locally or regionally in danger of extinction? (5) If the community type were lost, what species would also be lost or, at least, severely disadvantaged?

3. **P2 · Genetic Diversity Along Gradients: Determine the genetic diversity of the dominant plant species along a latitudinal and successional gradient with and without livestock grazing.**

One to three of the dominant species would be selected for starch-gel electrophoresis and/or Randomly Amplified DNA (RAPD) studies to compare the quantitative heterozygosity of populations: (1) in pristine and in degraded sites; (2) along a latitudinal gradient to estimate spatial variation among populations; and (3) between grazed and ungrazed sites with similar stable states. Pristine and degraded sites should be near one another so that exchange of genetic material is feasible between populations. The latitudinal gradient will provide a measure of the among population variation. For the grazed and ungrazed comparisons, large (> 1 ha) long-term grazing exclosures should be used for the ungrazed plots. These exclosures should be in place for a minimum of 20 years to provide a minimum time for selection, if any, to occur. Areas such as the Idaho National Energy Laboratory may provide large areas that have remained ungrazed for nearly 50 years. A minimum of 15 enzymes (preference for 20 or above) should be examined.

4. **P2 · Monitor changes at community and landscape levels through time.**

Track changes in vegetation diversity at the community and landscape levels over time. Using satellite images (AVHIR or TM) and Geographic Information System (GIS) technology, map current community types and compare among years for changes within communities and among communities across BLM lands within the project area. Specific attention should be made in describing the expansion of weedy species. Attempts will be made to determine associations between changes in communities and in land uses or disturbances such as wildfires.

5. **P3 · Faunal Diversity: Determine the species richness and composition for some of the major animal groups (e.g., insects, mammals, birds) in pristine, degraded, and revegetated communities.**

Although the project emphasizes plant diversity across the landscape, we recognize that ecosystems are composed of interacting plants and animals Therefore, we propose complimentary studies to monitor animal species composition and richness. These studies could categorize animals into guilds such as granivores, herbivores, and predators. Such an organization may provide useful information for restoration efforts. For example, if degraded sites have equal or higher numbers of granivores, but fewer predators than nondegraded sites, then reseeding efforts may be jeopardized by granivores. Restoration efforts may require adjustments to compensate for the expected granivory.

Study sites will need to be large enough to adequately compensate for the sample area needed for animals with large home ranges. Studies should be adequately replicated across the landscape to provide a measure of the variation among sites.

III. Competition and Establishment

Restoration of plant diversity will require an understanding of factors contributing to plant competition and establishment. Plant establishment is governed not only by seed and seedling physiology, but by beneficial and detrimental interactions among plants during the establishment phase. Undesirable plants tend to be particularly competitive with desirable plants during the establishment phase (years 1-5) of development. Success in seeding rangelands depends in part on a proper understanding of the competitive relationship among desirable and undesirable species during the establishment phase and an understanding of how management activities may reduce competitive interference.

Innate differences in competitive ability among desirable species may strongly influence the establishment of species included in mixtures as well as with species currently occupying a site. Properly applied seeding methods and other cultural practices may sometimes compensate for competitive differences among species when attempting to establish a mixture of species.

Research on competition and establishment must consider the type and length of control of undesirable plants necessary to allow establishment of native species. Methods for control and management of undesirable plants are varied including mechanical methods, herbicides, biological control, and fire. Appropriate method(s) will depend on the specific undesirable plant(s), site characteristics, management objectives, and economics.

A. Competition: Evaluate the competitiveness of selected native plant species, individually and in mixtures, and of ecotypes when grown in association with undesirable plants; and evaluate compatibility among desirable native perennials to determine potentials for coexistence.

1. **P1 - Determine density-dependent effects and quantify relative aggressiveness of desirable and undesirable species.**

Studies using addition-series (density-dependent effects), substitutive (aggressiveness) designs (Silvertown 1987, Radosevich and Holt 1984), or other appropriate designs should be used to determine the relative competitive abilities of targeted species. Competitive abilities of both desirable and undesirable plants can be evaluated under highly controlled conditions. Initial studies may be conducted in the greenhouse to quantify density-dependent effects and to evaluate aggressiveness of interacting species.

Greenhouse, or other off-site, experiments should be conducted using soils from potential reseeding sites to ensure inclusion of indigenous microbes. The root zone in these studies should be maintained at temperatures similar to those occurring on potential reseeding sites. Initial studies should evaluate squirreltail and medusahead or cheatgrass because of squirreltail's potential to maintain and possibly expand on sites dominated by exotic annuals. Future studies should evaluate the competitiveness of basin wildrye, Indian ricegrass, Thurber's needlegrass, and bluebunch/Snake River wheatgrass with exotic annuals. Additional studies can evaluate other species identified as priority species in Vegetation Diversity Project: A Research and Demonstration Program Plan (May 1990).

2. **P1 - Evaluate competitive interactions of desirable and undesirable species under variable climate conditions and soils of potential reseeding sites.**

Follow up field studies (to the studies in 1 above) will be required to further evaluate competitive interactions of desirable and undesirable species under variable climate and soils conditions (communities prioritized elsewhere in this document) similar to those on which reseeding efforts are anticipated.

Initial studies should focus on squirreltail as the desirable native perennial plant and medusahead as the undesirable plant. Squirreltail plants and seed should initially be from proposed areas of intervention. Similar evaluations for Thurber's needlegrass and for the native wheatgrasses would be of lower initial priority.

This objective would have to be addressed in two studies that could be conducted simultaneously: (a) Seed known densities of squirreltail into small, replicated plots. Within those plots, maintain a range of medusahead densities by hand weeding through the growing season. Evaluate squirreltail and medusahead germination, survival, growth curves, production and reproduction under conditions of varying densities. (b) Transplant plugs of squirreltail seedlings into small, replicated plots during the fall. Irrigate if necessary to initiate establishment. Use vispore or some other method to suppress competition during the first growing season then allow medusahead encroachment and/or provide medusahead seed to provide a range of initial densities. Evaluate established squirreltail survival, growth curves, production, reproduction and spread across a range of initial medusahead densities.

3. **P1 - (a) Evaluate community level responses of plants and soils, and individual plant responses to a shift in precipitation pattern from predominantly winter to a more summer oriented regime. (b) Determine the interaction effects of precipitation pattern shifts, as described in (a) above, and increasing CO_2 levels on competitive interactions among desirable and undesirable plant species.**

Atmospheric CO_2 levels are higher than they have been in the recent past and are projected to continue to increase. Higher levels of atmospheric CO_2 have the potential to increase both air and ocean surface temperatures, which in turn influence global circulation patterns. Shifts in global circulation patterns may alter the distribution and amount of precipitation in the Great Basin. Elevated CO_2 levels should provide an advantage to cool-season (C_3) species, but a shift to summer precipitation should provide an advantage to warm-season (C_4) species. Competitive interactions among species may favor exotic annuals or native perennials or may have no effect should major climate changes occur in the Great Basin. Therefore, studies are needed to evaluate potential effects climate change may have on soils and on species composition, richness and structural diversity of vegetation in the sagebrush-steppe region.

Studies should examine (1) community level responses (e.g. dominant grass, forb and shrub responses, both physiology and structure; soil nutrient cycling; and mycorrhizal activity) resulting from shifts in precipitation season from predominately winter to a more summer oriented regime, and (2) germination, establishment, and interspecific competition among dominant species in Wyoming big sagebrush communities. Both field and growth chamber studies will be necessary. Field studies could utilize rainout shelters coupled with supplemental irrigation to provide shifts in precipitation patterns. Measurements should include soil moisture at incremental depths; soil nutrient dynamics, primarily C, N and possibly P; mycorrhizal activity, spore counts (spring, summer, and fall) and root colonization (during boot stage of development); plant community composition on the basis of basal cover; seed bank composition; shrub and herbaceous root density and distribution; and photosynthetic activity, reproductive effort, growth, and tissue nutrient contents of the dominant shrub (Wyoming big sagebrush), grass (squirreltail, bluebunch wheatgrass, Sandberg's bluegrass, and/or medusahead or cheatgrass), and forb (e.g. vetch) species. Growth chambers should be used to evaluate differences in air temperature, root temperature, relative humidity, soil moisture, and concentrations of CO_2. Species to be evaluated should include: a dominant forb; Wyoming big sagebrush; one of the following cool-season perennial grasses: Thurber's needlegrass and/or bluebunch wheatgrass; Sandberg's bluegrass, Indian ricegrass, basin wildrye; exotic annuals such as cheatgrass and/or medusahead; a warm-season grass such as sand dropseed *(Sporobolus cryptandrus)*; and some special status plants.

4. P1 - Develop demonstration/research plots to compare methods of competition control to aid establishment of desirable plants on annual plant dominated sites.

Utilize methods identified by previous research which have shown potential for control of cheatgrass and medusahead. Atrazine, dalapon, and paraquat, herbicides found effective in past studies, are no longer registered for rangeland use. Evaluation of these herbicides will not be considered as viable alternatives with the Vegetation Diversity Project unless reregistration for rangeland use becomes a reasonable possibility. Study/demonstrations should evaluate level of suppression and timing of control necessary for establishment. Treatments should be replicated at least 3 times to allow statistical analysis and interpretation of results. The following combination treatments should be evaluated:

Seed squirreltail into established medusahead or cheatgrass sites. Evaluate treatment combinations of fire, tillage, livestock grazing, and herbicides such as glyphosate and 2,4-D for effectiveness in control of competition to aid establishment of desired perennial species. Examples of treatment combinations include, but are not limited to: (a) spring/early summer tillage followed by fall, post-emergent application of glyphosate and immediate seeding of the desired species; (b) early summer fire, subsequent spring glyphosate (post-emergence), and fall seeding; and (c) heavy livestock grazing in late spring on annual grass sites to reduce the annual grass seedbank and the subsequent seedling population that would compete with establishing desirable seed sown in the subsequent year. Objectives of the research are to evaluate control of undesirable plant competition and stand establishment of the desirable seeded species. Alternative seeded species could be bluebunch wheatgrass, Thurber's needlegrass, etc. depending on site. Logistics permitting, evaluation of techniques in both medusahead and cheatgrass sites would be preferable. Collaboration with the Intermountain Greenstripping and Rehabilitation Research Project (BLM, Idaho State Office) may facilitate completion of these studies.

5. P1 - Evaluate different sequences and patterns of seeding mixtures of desirable species as means of establishing diverse native communities.

Different sequences and patterns of seeding desirable seed mixtures may help overcome problems associated with differing periods of growth and competitive abilities and facilitate establishing diverse native communities. Comparisons anticipated include: (1) mixing herbaceous and shrub seeds together in a single seed mixture and drill seeding; (2) mixing herbaceous seeds together in a single seed mixture and drilling immediately before transplanting shrub seedlings (leave outside drill rows empty for transplanting shrubs); (3) providing spatial distribution by separating herbaceous species sown by rows and transplanting shrubs into outside drill rows; (4) providing spatial distribution by stratifying species into "islands" (perhaps by favorable microsites if variable microsites are present on a site, less competitive species can be concentrated on those sites more favorable for establishment); and (5) providing temporal distribution by seeding perennial grasses first, allowing establishment, and following with interseeding or "island" patch seeding of forbs and shrubs. Species will be site dependent and should represent potential native species for the site. Row widths of 10 to 14 inches are most commonly used in range seedings. Row spacing of 12 to 14 inches have been recommended over narrower rows where there is a premium on moisture and when deep-furrow drills are used. Survival, production, reproduction, and movement of the species involved will be an important part of this study.

6. P1 - Evaluate the cost and effectiveness of alternative techniques to incorporate broadcast seed into the soil in areas where seed drills cannot be used.

Various regulations and physical constraints restrict the use of standard drills in many areas for which restoration is a priority. However, many seeds require adequate contact with soil for successful germination and survival. This study would investigate the feasibility of: (1) broadcast sowing seeds on such areas during late autumn and using livestock to trample seed into the moist soil; (2) animal or human drawn drag or harrow; (3) transplants; (4) snowbank seeding; and (5) broadcast only.

7. P2 - Evaluate the role of soil microorganisms (mycorrhizae, rhizobium, etc.) in restoration of native plant species on degraded sites.

Addressing this objective will require two studies that could be conducted simultaneously:

(a) A study is needed to assess the changes in the microbial community (population levels and species composition) that may result from a shift to an exotic annual community from a native plant community. Soil samples from annual dominated and from native plant dominated communities will be analyzed for microbe density and species composition. Roots from desirable plants in native plant dominated communities and from medusahead, cheatgrass and knapweeds in undesirable plant dominated communities will be analyzed for percent colonization by and species identification of vesicular-arbuscular mycorrhizae (VAM).

A recently completed study from southern California indicated that the VAM species composition changes when communities become dominated by annuals. The reintroduced perennial species can enhance fungal recovery after five months in those systems (E.B. Allen, pers. comm.).

(b) Field studies are needed to compare establishment success by VAM infected and uninfected plants. VAM infected seedlings of squirreltail, bluebunch wheatgrass, Idaho fescue, and/or Thurber's needlegrass should be transplanted into medusahead and/or cheatgrass dominated sites which have been sampled for resident spore occupancy. A split plot approach could be used to evaluate the influence of competition suppression vs. no suppression during the first growing season. Perennial grasses will be evaluated for survival, production, and level of VAM root colonization. Plants and soils will be sampled for levels of N and P.

8. P2 - Evaluate the genetic component of the competitiveness of native perennials from deteriorated vs pristine sites using (a) ecological genetics and (b) quantitative genetic approaches.

Individuals of desirable species can often be found on degraded sites, therefore, the potential exists that these individuals have gone through a selection process that favored genotypes that tolerate competition with exotic annuals. Species of interest include squirreltail, bluebunch wheatgrass, Thurber's needlegrass, Indian ricegrass, basin wildrye, and perennial forbs such as globe mallow, buckwheats, and penstemon. Should evidence for selection be found in degraded populations, then collections for developing commercially available seed or for restoration should concentrate their seed collections on desirable plants in degraded sites.

(a) Seeds and clones of desirable species should be collected from individuals on degraded sites and on pristine areas. Seeds and clones will be categorized in a collection site (degraded vs. pristine) and a relational hierarchy: populations, families, sibs or clones. Seedlings or clones will be grown at a field location with or without competition from an exotic annual (e.g., medusahead or cheatgrass). The annual will be maintained at a standard density and neighborhood area. A minimum of six populations, ten families per population and ten sibs or clones per family will be examined. Measured parameters will include: aboveground biomass, seed production, tiller or clonal production, and survival.

(b) The quantitative genetic approach might use starch-gel electrophoresis studies to complement ecological genetics studies of (a) above. Other quantitative techniques may be more effective than starch-gel electrophoresis. If so, they should be used. Comparisons of quantitative heterozygosity would be made of populations from pristine and degraded sites located close enough to one another so that exchange of genetic material is feasible between populations. These studies would look specifically for reductions in heterozygosity in degraded populations that might indicate selection for quantitative traits that may favor the survival and reproduction of individuals from degraded populations.

This study fits within both Competition (III) and Plant Materials (IV) categories. See also study IV.A.2.

B. Island Establishment: Evaluate the "island" approach to establish native species into ecosystems dominated by exotic annual plants.

1. **P1 - Compare techniques and costs for establishing islands of desirable species on lands domlnated by exotic annuals.**

This study would compare: (1) the use of transplants vs. seeding desirable species; (2) preparation treatments (e.g., herbicide vs. fire, etc.); (3) the use of mulches for competitor control and for growth enhancement; and (4) the location within the island. These studies would use one island size (e.g., 10 x 10 m) (see comparisons of island size below). The species should consist of two shrubs, two grasses and two forbs. Island establishment of squirreltail in medusahead is a high priority species for study in this section. Records will be kept of all costs, including labor, so that an economic analysis could be incorporated. Survival, growth and reproduction of the desirables and of the exotics will be measured annually within each treatment. This study would be repeated annually for at least three years to determine the variability among establishment years.

2. **P1 - Determine how island size, shape and topographic location affect the establishment and dispersal success of the study species.**

Dispersal success can be measured as the establishment of a propagule away from the parent plant. Success is achieved through a combination of sufficient reproduction and effective dispersal. The size and shape of an island can affect the number of individuals that are reproductive. Those individuals along the edge of the island may have different (more or less) reproduction relative to central individuals. Locating islands on hillsides rather than valleys may favor dispersal. The distance from the edge of the island may influence this relationship. Size is an important factor concerning invasion of exotics into islands. The closer to the edge of an island the more likely an exotic may invade the island. Size is also important with respect to potential for loss of the island to insects, small mammals, grazing animals, and fire.

Therefore, we believe that reproduction of desirable plants relative to their distance from the edge of an island needs to be determined. Results from these correlations between distance and reproduction will help to determine an appropriate size and shape of island.

Estimates of establishment and survival of exotic species relative to the distance from the edge to the interior of the island are also necessary for determining appropriate size and shape.

Island establishment of squirreltail in medusahead is a high priority species for this study.

C. Specialized Methods for Establishment: Evaluate the availability of and need for specialized methods for seeding or establishing desired species.

Much of the conventional equipment and technology currently available for use on rangelands are not allowed for revegetation efforts within BLM Wilderness Areas and Wilderness Study Areas. Heterogenous site conditions will require a variety of methods and equipment to revegetate target areas with desirable species. Methods listed below merit attention. As they are developed, new methods and equipment should be evaluated as appropriate.

1. **P1 - Evaluate the effectiveness of animals as a dispersal agent for desirable and undesirable species.**

Provided seeds of desirable species could withstand the digestive system of the animal, deposition of seeds in fecal material may provide an effective means of dispersal while concurrently providing a safe-site for germination and establishment. Studies will be conducted in two phases.

First, seed-passage tests would be conducted to determine the ability of seeds of native desirable and undesirable species to pass through the digestive system of several domesticated and wild animals found in this ecosystem and remain viable. These studies will be compared to seed viability studies between (a) seeds coated with materials to enhance their ability to pass through the digestive system and (b) prefeeding treatments to decrease the passage time within the animal's gut.

The second phase would take the promising techniques from the first phase and would examine the germination and survival of seed in feces versus broadcast seeding and transplanting techniques.

Should this technique appear to be useful for some species, then an economic cost analysis should be conducted to determine the cost effectiveness of the various techniques.

This study could be combined with study III.A.6. to provide a more comprehensive evaluation of animals to both distribute and incorporate seed into the soil.

2. **P3 - Evaluate the likelihood of livestock ingesting and dispersing undesirable species if livestock grazing is used as a control for an undesirable plant. Also, evaluate the dry lot requirements for livestock that are used as control agents of undesirable species.**

Sheep are currently used to graze leafy spurge in areas of the Great Basin and Columbia Plateau during the time when leafy spurge is flowering and fruiting. Studies need to be initiated to determine: (1) the likelihood of leafy spurge seeds passing through the digestive track of sheep and remaining viable; and (2) the passage time for 100 % of the viable seeds. These results could provide an estimate of the risk of dispersal of undesirable species by livestock. Species such as cheatgrass, medusahead, various knapweeds, statthistle, leafy spurge and white top should be evaluated for potential of spread through feces.

D. Prescribed Fire to Control Competitors: **Evaluate the how prescribed fires can control undesirable annuals or reduce sagebrush dominance.**

Fire can be a useful tool in reducing competitors when seeding native perennials and in releasing grasses and forbs from competition with fire-sensitive shrubs.

For annual species that retain seeds in inflorescenses as the remainder of the plant begins to dry and senesce, there is a period when seeds are susceptible to fire. Burning the plant too early (before flowering) or too late (after dispersal) may have little or no effect in reducing the seed population of annuals. Research from California indicates that fire, when used at the correct time, can reduce the next year's population of medusahead.

As sagebrush becomes dense, it can suppress grass and forb production. Prescribed fire can be used to release grasses and forbs because sagebrush is a fire sensitive species. Provided desirable grass and forb populations are sufficient and exotic annual populations are low, there is no need to reseed. However, the levels of desirable vs. undesirable need to be determined.

Total removal of sagebrush from a watershed is not desirable, but we would like to create a mosaic with sagebrush dominated areas and grass-forb dominated areas. The development of techniques to achieve this mosaic is necessary.

1. **P1 - Demonstrate the window of opportunity for prescribed fire to reduce medusahead seed banks and densities.**

We propose a demonstration study where prescribed fires are set at three different times, (before dispersal, mid-summer after dispersal, autumn after dispersal) and an unburned control. Heavy spring grazing and treatment with glyphosate during the spring before burning should be evaluated as possible combinations with fire. Heavy spring grazing may reduce the fuel load too low for subsequent fire. Glyphosate prior to seed set might prevent an additional seed source if fire is delayed beyond seed set but still allow fire to remove the medusahead litter mat. Video tapes will be used to describe the pretreatment area, the burning techniques used, and the postfire impacts. Combinations of fire with post-fire treatments would be desirable (e.g. a combination of spring burning and fall herbicide or grazing followed by seeding desirable species). Tapes will be distributed as an instructional aid. Tours would be given the following spring to BLM, USFS, and State fire and revegetation personnel to demonstrate the effect of timing.

2. **P2 - In sagebrush dominated areas, determine the levels of desirable grass and forb populations and of exotic plant populations that allows communities which develop after fires (prescribed and wild) to become dominated by desirable or undesirable plants.**

This study would require an area with varying densities (e.g., three to four density levels) of desirable and undesirable plants associated with sagebrush. These would be burned mid-summer (wildfire simulation) and autumn (prescribed fire). The response of the grasses and forbs will be measured using basal cover and/or production during the next three years. Seed production per individual will be measured for the undesirable plants. Soil N and P should be measured pre-fire and at the beginning and end of each of the three subsequent growing seasons. This should be replicated either in space or in time.

3. **P2 - Enhance species diversity on sagebrush dominated sites by using prescribed fire to create a grass-forb mosaic within sagebrush dominated sites.**

For many wildlife species, the optimal habitat for all stages of development may be a combination of sagebrush dominated sites associated with grass-forb dominated sites found in a mosaic across the landscape. A study is necessary to determine techniques for burning sagebrush dominated sites so that only parts of the sagebrush community burns, but the associated vegetation remains intact. A criterion for site selection includes site domination by sagebrush, but with an understory of perennial herbaceous vegetation with few or no exotic annuals in the understory. Two approaches might be compared. The first approach would burn sagebrush during a season with a higher fuel moisture level than those recommended for total sagebrush control. The second approach would use a propelled ignited fuel-gel sprayed on small areas of sagebrush during winter when grasses are covered by snow. These two approaches would be compared in their ability to reduced the sagebrush dominance while not injuring the associated grasses and forbs. The influence of each technique on soil N and P should be monitored throughout the study.

The study might require two phases. The first phase would incorporate experimental small plots to test the feasibility of these approaches. The second phase would be larger demonstration level plots that would include economic as well as biological analyses.

E. Nutrient Availability and Competition: **Determine the role of nutrient availability and depletion, and of spatial distribution of nutrients on the competitive ability or establishment success of desirable and undesirable plants.**

Disturbance often results in high nutrient (nitrogen) availability which in Colorado tends to favor the establishment and growth of exotic annuals. As N becomes tied-up by soil microbes which are slowly decomposing litter, the dominance of desirable native plants appears to be facilitated. Also, relatively undisturbed sagebrush-steppe stands tend to show a high degree of spatial variability in nutrients which may limit the sites for exotic annuals to establish, however, the spatial variability in stands of annuals is unknown. We propose a set of studies to determine if nutrient availability and nutrient cycling may influence the growth and competitive abilities of desirable and undesirable plants.

1. **P2 - Determine if native perennials are able to compete and establish better with exotic plants if nitrogen is made less available by adding carbohydrates to the soil.**

Compare seedling establishment of mixtures of exotic annuals and native perennials with and without carbohydrates (e.g., sucrose, slow decomposing mulch) being added to the soil. These studies would be conducted on disturbed and undisturbed sites and on recently burned areas. Plant survival, aboveground biomass, and seed production would be estimated for each treatment. These studies would also monitor nitrogen availability and VAM (vesicular-arbuscular mycorrhizae) infection as well as the plant growth characters.

2. **P3 - Determine the ability of shrubs, forbs and grasses to access nutrients when they become available either in patches across the spatial landscape or in pulses through time.**

This study addresses the question of why sagebrush becomes the overwhelming dominant on sites in the absence of grazing and fire. Is sagebrush better able to acquire nutrients found in patches or pulses? Nutrient acquisition can be measured using stable isotopes. Plant responses would include current year's growth and seed production. Mixtures of grasses, forbs and shrubs, including desirable and undesirable plants would be compared.

F. Animals as Agents of Biocontrol and Stimulatory Growth: **Examine the effectiveness of using livestock or other animals as control agents of undesirable plants.**

Insects are the common agent used in biological control systems. We do not recommend providing Vegetation Diversity Project support for preliminary research on biological control of exotic species with insects, however, we are supportive of this work and believe it is a vital component in comprehensive weed control program. Currently, insect biological control agents are not the recommended course of action for the control of most exotic species. However, we would support cooperative demonstrations if proven insect control agents were found that reduce competition of exotic annuals during revegetation.

We advocate investigating grazing systems that can limit the detrimental impacts of grazing on desirable native plants while identifying opportunities for developing grazing systems to reduce undesirable species in the ecosystem.

1. **P3 - Evaluate the potential for use of domestic animals to control or reduce brush cover and increase grass and forb cover and production.**

Examples of two potential studies are described below:

(a) Evaluate heavy fall use by sheep coupled with spring deferment on sagebrush-grass range sites to reduce sagebrush and increase grass and forb cover. Sites for this study would require a high initial sagebrush cover (greater than 12% crown cover). The site must also contain a sufficient coverage of desirable grasses and forbs (two or more desirable plants per m2) to respond to a reduction in sagebrush cover. These studies would be conducted in small pastures. The study would be conducted over several years (2 to 3). Sagebrush survival, grass production and grass/forb seedling establishment would be compared against control sites. Broadcasting forb seed before sheep entry to allow sheep to trample seed into the soil may be also examined for its success in enhancing forb establishment (see study II.F.3. below).

(b) Evaluate the potential for using goats to manipulate shrub cover and density for maintenance of desirable communities. Evaluate spring, summer, and fall goat (does and kids, in pairs and separately) utilization of sagebrush, rabbitbrush, and juniper to reduce shrub densities and cover and enhance grass and forb production. Study sites must be in areas where sagebrush and/or rabbitbrush density reductions are desired and where juniper encroachment onto shrub-steppe sites is occurring and junipers are less than approximately 6 feet tall. The study should evaluate timing and intensity of goat use needed to impact shrubs; goat diets; and shrub, grass and forb responses. An absence of special status plants must be a criterion for site selection.

2. **P3 - (a) Evaluate the potential for late-spring and early-summer grazing of grasses and forbs by cattle and/or sheep to stimulate growth and reproduction of bitterbrush.**

(b) Evaluate the impact that ungulate browsing is having on bitterbrush growth and reproduction.

Reduced livestock grazing pressure on grasses and forbs is suspected in many areas of the western U.S. to be reducing the growth and reproduction of many desirable shrubs, such as bitterbrush through increased competition by grasses and forbs while deer population increases have been placing greater browsing pressure on desirable shrubs. A study or combination of studies would be designed to determine the role of livestock grazing of grasses and forbs and of wildlife utilization of shrubs on the growth and reproduction of the shrubs. Increased cattle use during the late-spring and early-summer season for a series of three to five years may impact grasses and forbs enough to allow bitterbrush sufficient time to respond. After the three to five year study period, livestock use would revert to early-spring and/or fall to allow grasses and forbs to recover.

This study could be conducted using a combination of small pastures with controlled grazing and of exclosures to eliminate wildlife use. The bitterbrush response would be measured by estimating current-year's growth and seed production and by monitoring seedling establishment. Utilization of bitterbrush would also need to be measured. Species composition based on aboveground biomass of grasses and forbs would be monitored annually to determine the effect on the related grasses and forbs during the study period.

IV. Plant Materials and Seed Technology

Research needs in the area of plant materials evaluation and seed technology include determining the need for and identification of ecotypes of desirable native species for use in targeted areas; seed physiology, morphology, and viability; seedling and seedbed ecology of selected plant species/ecotypes; and technology required for production, handling and planting of seed of the selected species/ecotypes. Common gardens can serve as demonstration and evaluation plots of species and ecotypes within species for adaptation to site and of potential competitive abilities.

A. Ecotypes and Phenotypes:

(a) Evaluate ecotypic variability vs phenotypic plasticity within native plant species adapted to target areas.

(b) If ecotypic differentiation is an important component, then identify and select those ecotypes best adapted to target areas.

Very little appears to be known about ecotypic variability versus phenotypic plasticity in native species likely to be used for restoration of severely degraded Great Basin and Columbia Plateau rangelands. Large phenotypic plasticity for a given species might allow use of seed produced from other locations including commercially available seed. Large genetic variability would suggest the need to use site specific ecotypes in revegetation/restoration attempts. If genetic variability is significant, variables important to the relative success of the ecotype at its original site and at the target area will need to be identified.

1. **P1 · Compare the genetic and phenotypic variability of important native species for revegetation/restoration efforts in the Great Basin and Columbia-Snake River Plateau.**

Ecotypic differentiation can be evaluated through common garden and reciprocal transplants or seedings of species from sites with variations in elevation and precipitation amounts and patterns. Commercially available cultivars should be included in the studies. Evaluations should be made of phenology, morphology, timing and rates of growth, survival, seed production, water use efficiency, and physiological functions. Common gardens should be replicated in at least three locations within the Great Basin. Each common garden should have a climate station to monitor at least daily temperature extremes and precipitation. Preferably, soil moisture would be measured at 5, 15, and 25 cm (or at 15 cm increments if using a neutron probe). Species of immediate interest to the Vegetation Diversity Project include the grasses squirreltail, bluebunch wheatgrass, Snake River wheatgrass, Thurber's needlegrass, needle-and-thread, Indian ricegrass, and basin wildrye. Forbs should include globe mallows, buckwheats, and biscuitroots. Shrubs should include sagebrush, rabbitbrush, bitterbrush, shadscale, and winterfat. Work on bluebunch wheatgrass, Snake River wheatgrass, Thurber's needlegrass, and needle-and-thread was begun in 1988 for selections of superior genotypes by cooperators to the Intermountain Greenstripping and Rangeland Rehabilitation Project. We intend to coordinate any collections of seeds of these species with the IGRRP to reduce any duplication of effort.

2. **P1 · Analyze seed germination characteristics of important native species for revegetation/ restoration efforts in the Great Basin and Columbia-Snake River Plateau.**

Analyze seed germination syndromes from different populations and commercially available accession of the species of interest to the project (refer to IV.A.l. above). Evaluate germination differences among different populations under conditions that might indicate heritable traits associated with germination as opposed to environmentally-induced traits. Differences in germination behavior among populations that are related to genetics are crucial for determining whether a species can successfully revegetate itself in any specified environment. Those characteristics that are regulated by environmental conditions of the parental stock may help managers and seed producers match environmental conditions that will improve the likelihood of establishment success.

3. **P2 · Use quantitative genetic evaluations to help evaluate genetic variability within and among populations of natives.**

In addition to common garden evaluations of native perennial populations, quantitative genetic data would help evaluate genetic variability within and among populations. Starch gel electrophoresis has been used to obtain quantitative genetic data. Use of DNA fragment length polymorphism has been suggested to recover genetic information quickly and efficiently if fragments are generated using RAPD (Randomly Amplified Polymorphic DNA) procedures. This technology apparently provides great power in describing the basic genome of species, varieties, and individuals (Kimball T. Harper, pers. comm.). Percent heterozygosity among populations, among families and within families needs to be examined to estimate the quantitative variability within important dominant native plants that are distributed over a wide geographic range. Comparisons should be made between local populations and commercially available stocks of native species. This would provide quantitative evidence for the concerns of introducing populations from other locations. See also studies ll.A.3 and lll.A.8.

4. **P2 · Support native plant germplasm collections and evaluations for native plant breeding programs.**

Little work is being conducted on native grass breeding, germplasm collection, evaluation, and improvements for species from the Great Basin and the Columbia Plateau. The exceptions are the efforts of SCS Plant Materials Centers, USDA-ARS, and USDA-FS. Species are identified that are potentially important for revegetation efforts, but are specifically limited by a feature such as awned seed, seedling vigor, seed dormancy, etc. which can likely be ameliorated by plant breeding. Care should be used when working with self-pollinated species to reduce the likelihood that characteristics eliminated by breeding are not totally eliminated from the population. This may be achieved by using impure (regarding the character) lines such as combinations of dormant and nondormant seeds. Also, breeding techniques that culminate with backcrosses into the native or into the key species' parental line are encouraged. Backcrosses tend to retain a high proportion of the original genotype in the offspring along with the character that was selected. This would then allow natural selection to favor genes for each location including those genes removed by the breeding process. Continuation and expansion of this work should be encouraged. Work currently underway, of specific interest to Vegetation Diversity Project, which would benefit from support include: (1) selection of bluebunch wheatgrass and thickspike wheatgrass for dry matter production during the establishment year; (2) accession evaluations of bluebunch wheatgrass, Snake River wheatgrass, thickspike wheatgrass, Basin wildrye, beardless wildrye, and indian ricegrass; and (3) accession collection trips to the Columbia Basin of Washington for Snake River wheatgrass, bluebunch wheatgrass, and indian ricegrass. Additional work of interest to Vegetation Diversity Project would 'focus on collections and evaluations of accessions of squirreltail and of forbs such as buckwheats, biscuitroots, and globe mallows.

5. **P3 - Determine the level of population hierarchy that is most useful for plant material selection for revegetation/restoration.**

Through a combination of common garden evaluations and quantitative genetic data, a study to determine the level of population hierarchy that is most useful for plant material selection for restoration/reclamation would be useful. The levels might be: populations within communities, communities within watersheds, watersheds within physiographic regions, and between physiographic regions. Alternatively, an approach might be to examine populations varying in distances among several overlapping foci.

B. Problem Diaspores: Develop techniques to enhance the establishment of native species that are difficult to sow with standard equipment.

1. **P1 - Evaluate the various methods and technologies for sowing 'problem' diaspores.**

Diaspores are seed, fruits, fruits with attached structures, or even flowerheads or whole aerial plants with several to many seeds dispersed as a reproductive unit. Diaspores that are fluffy, hairy, awned or otherwise incompatible with standard drills, or that are adapted to surface germination and require assisted fixation to keep the seed in place, pose special problems in mechanized sowing. Several methods and technologies are currently available for sowing 'problem' diaspores. Techniques that should be evaluated include drills with metering devices that can handle fluffy or appendaged seed; broadcasting combined with land imprinting on loose or coarse soils; seedbed treatments to disturb the soil before or after simple broadcast seeding; broadcasting onto snowbanks; hydroseeding; and fluid drilling (gel seeding). Evaluation of the various techniques with species of interest to the Vegetation Diversity Project would be very useful as applied research and as a technology transfer tool. Collaboration with the Intermountain Greenstripping and Rehabilitation Project (BLM, Idaho State Off ice) might facilitate accomplishment of this objective and provide needed information for both projects. Species of interest to Vegetation Diversity Project include bluebunch wheatgrass, Snake River wheatgrass, squirreltail, basin wildrye, Thurber's needlegrass, needle-and-thread, Indian ricegrass, various sagebrush species and subspecies, fourwing saltbush, winter-fat, and possibly rabbitbrush species.

C. Seed Priming: Develop techniques to reduce the germination time for native species.

1. **P3 - Evaluate seed priming techniques to enhance early germination of native species.**

A considerable amount of seed priming work has been done with Indian ricegrass and winterfat. Seed priming techniques should be examined particularly for hard-seeded forbs such as Lewis flax, globe mallows, buckwheats, biscuitroots, and yarrow. Seed priming may also prove useful for desirable perennial grasses, in addition to Indian ricegrass, as an aid in concentrating germination and initial establishment and increase site occupancy in areas where weed competition is likely to be a problem. If seed priming can facilitate initial site occupancy, breeding for uniform germination may not be necessary and/or it might be possible to shorten the length of period needed for weed control without sacrificing natural variability of native species germination. Evaluation of mechanical and chemical scarification, temperature, and light effects on germination of desirable perennial species may provide information useful in developing seed priming techniques. Species of immediate interest to the Vegetation Diversity Project include the grasses squirreltail, bluebunch wheatgrass, Snake River wheatgrass, Idaho fescue, Thurber's needlegrass, needle-and-thread, and basin wildrye.

V. Maintenance of Desired Native Vegetation

The ability to maintain lands that currently have, or are restored to, a desired state of native plant diversity is critical to long-term success of sustained multiple-use of BLM lands. Restoration to and/or maintenance of desired plant communities requires an understanding of the nature of the dynamic equilibrium of desired communities, factors influencing that equilibrium, and conditions necessary to maintain desired levels of selected plant species in a given plant community. Many of the studies described below can be incorporated into studies identified in Competition and Establishment (Ill) and Plant Materials (IV) studies described above.

A. Demography and Life History: **Descriptions of demography of the important life stages of dominant desirable and undesirable species.**

1. **P1 - Establish long-term permanent plots to compare the demography of dominant desirable and undesirable species when grazed and ungrazed and when grown in native-dominated and exotic-dominated communities.**

Three general studies would fall under this objective. They include (a) seed longevity, (b) annual seedling germination, establishment and survival, and (c) adult survival and seed production. These studies will be located near a long-term weather station so that census information can be associated with precipitation and temperature events.

(a) Seed Longevity: Examine the viability and germinability of seeds buried (5-cm deep), of seeds in litter at the soil surface, and in dry ambient conditions. Replicated samples of shrub, forb and grass seeds will be located in at least three field sites across the Great Basin and Columbia Plateau. Seeds will be placed in the field each year for the first five years. Seeds will be extracted from the field annually. Germinability and viability tests will be conducted to develop a time-course for seed longevity for each species.

(b) Seedling Survival: Known numbers of seeds will be distributed across the surface of plots on an annual basis. Seedlings will be censused monthly during the first year and annually in subsequent years using standard mapping techniques (Mack and Pyke 1983). These studies would be compared among years and among grazing treatments.

(c) Adult Survival and Seed Production: A minimum of 200 adult individuals of each species will be randomly selected and permanently tagged. The fate of these individuals will be monitored annually. Attempts will be made to determine the cause of death for individuals that died during each year. Reproduction per individual will be estimated annually by determining seed counts on a subset of individuals

Results from these three studies will be used to provide parameters for models to determine population viability estimates for each species for the next 50 years with and without livestock grazing (e.g., Department of Energy sites such as the Idaho National Engineering Lab).

B. Establishment of Undesirable Species in Desired Plant Communities:

Determine conditions for successful establishment of exotics in a diverse native community.

1. **P1 - Determine the roles of dispersal (or lack thereof), localized disturbance, and livestock grazing in regulating the spread of exotic species into diverse native communities.**

In areas where diverse native communities are established, known numbers of seeds of exotic weedy species (e.g., medusahead, yellow star-thistle, other knapweeds, etc.) will be intentionally sown across the surface of permanent plots. Germination, survival, growth, and reproduction will be monitored for each individual in each plot. All plants of the weedy species in the plot and around the plot would be removed before the end of the growing season to reduce the potential of the experiment introducing an exotic species to a site. This study would be repeated over several growing seasons to provide estimates of the variance in germination and survival of these species.

At the same time, estimates of seed bank longevity would be made for surface and buried seeds. These seed bank longevity estimates and the germination, survival, and reproduction estimates will be used to determine the risk of population explosion using population viability analyses (PVA).

Disturbances will be created in the upper 5 cm of the soil profile on areas of .25 m2, or areas with existing disturbance (e.g. ground squirrel occupation, ant hill areas, wildlife or livestock trailing areas, etc.) will be used. Plots similar to those described above will be established. Similar plots will be established in undisturbed areas. Results of these treatments will be compared to those of the controls using PVA.

C. Management for Desirable Communities: Studies are needed of management intervention techniques necessary or useful for maintenance of desirable communities.

1. **P1 - Evaluate an experimental expert system for use of prescribed fire in big sagebrush ecosystems. Determine the need for an additional expert system specifically designed for use in big sagebrush ecosystems.**

Prescribed fire can be a useful, effective tool for regulating shrub dominance and for enhancing species diversity in sagebrush ecosystems. An expert system to help managers determine under what conditions prescribed fire should be used to enhance diversity in sagebrush ecosystems would be a useful technology transfer program. Sufficient information exists to evaluate an experimental expert system (Wright et al. 1992). Sources of information which could be used to evaluate this experimental expert system for prescribed burning for use in sagebrush-steppe systems include Schmisseur and Miller (1985), Champlin (1983), Blaisdell (1953), Harniss and Murray (1973), Wright et al. (1979), Wright and Bailey (1982), Bunting et al. (1987), and Sapsis and Kauffman (1991). The Fire Effects Information System (FEIS) would provide additional information useful in evaluating the experimental expert system. FEIS is a computerized database type system designed to store and provide easy user access to information regarding effects of fire on plant species, plant communities, and associated animal species (Fischer and Brown 1991). FEIS is not an expert system, but it does provide a great deal of information about fire effects on numerous plant species occurring in semiarid western ecosystems, and it would be very useful as an information base in evaluating and/or developing an expert system. For further information on use of FEIS contact the Boise Interagency Fire Center at (208) 389-2676.

2. **P3 - Evaluate season of livestock use for compatibility with creating or maintaining. desirable plant communities.**

Timing and intensity of grazing influences the potential for invasion of exotic weeds into diverse communities of native perennials. Season of use has been implicated as an important variable in maintenance versus degradation of desirable communities. Since grazing is a dominant use on much BLM managed rangeland, studies to evaluate different seasons of use on desired plant communities are needed from a practical management perspective. Properly applied grazing/browsing treatments may be compatible with maintenance of desired plant communities and should provide a tool for creating or maintaining the necessary structure to support specific management objectives (such as browse production for winter deer range, quality forage for winter elk range, nesting cover, and forb production). Treatments to be compared should include deferred rotation grazing, fall-winter only use, spring only use, summer only use, and no grazing. The deferred-rotation treatment should include 3 or 4 pastures. Deferment periods should include late-winter through early-spring and late-spring through summer. The late-spring through summer period should encompass the apical meristem elevation stage of development through maturity for desirable, cool-season, perennial grasses. Depending on number of pastures and site conditions, fall through early-winter or independent fall and winter periods may be desirable. Treatments need to be replicated at least twice (preferably more) and occur within the same community type in the same relative desirable condition. Permanent plots should be established within each treatment pasture for the purpose of sampling shrub canopy cover, herbaceous basal cover, and production of all species. Plots will be measured at least twice a year. Once in middle to late spring to monitor early season forbs and grasses and once in early to middle summer (end of growing season) for exotic annuals, perennial grasses, forbs, and shrubs, including special status plants. Feasibility of this study will be dependent on locating suitable sites of sufficient size to include replicated treatments.

VI. Special Status Plants

Factors such as various land use activities (e.g. reclamation/restoration efforts, livestock grazing, ATV use, wildlife use, etc.), invasions of exotic plants, invasions of juniper, changes in fire frequency, and potential global warming may impact plant diversity through extirpation of special status plants. Examinations of ecosystems and ecosystem processes responsible for the occurrence of these species is required for their management and maintenance in the ecosystem. Species selected for study should have a common characteristic such as life form, seed dispersal mechanisms, germination requirements, or taxonomic relationship (e.g. genus, family). Currently, little documented information is available concerning these factors for special status plants. We recommend that the greatest effort be placed on compiling the available data for plants on BLM lands. We strongly urge the inclusion of special status plants in the experimental designs of previously mentioned studies and of demonstrations, when appropriate.

A. Demographic Studies of Special Status Plants: Collect information on the demography of critical special status plants and develop a data base for use in population viability analyses.

1. **P1 - Coordinate studies of population status and trend of selected special status plants using population viability analyses.**

Botanists at the state and district levels will be asked to provide demographic data on critical populations. High priority will be given to species with the potential of establishment at additional sites and low priority given to species that are edaphically restricted. Factors to be considered in studies include: population structure (age or stage), reproduction and establishment, timing and frequency of measurement, and current trend of weather, grazing, or competitors on selected special status plants. These data will be used along with modeling tools such as population viability analysis (PVA) to determine the risk of extinction and to determine the stages of the population (e.g. seed production, seedbank longevity, seedling survival) in which data collection is needed and on which management should concentrate.

B. Special Status Plant Restoration : Identify potential for restoration.

1. **P3 - Identify potential for restoration of special status plants.**

Utilizing information from life history characteristic studies above or information available from other sources, evaluate methods for restoration of special status plants on sites where they currently exist. Evaluate seeding and transplanting methods, the need for and methods of suppression of competition (e.g. herbicides, livestock utilization, fire, etc.), and/or changes in land management (e.g. grazing vs no grazing, wildlife exclusion, exclusion of recreational access, etc.) to facilitate the maintenance and spread of special status species.

Life history and reestablishment information from studies done at sites where a special status plant population currently exists will be used to attempt reestablishment on sites where it does not currently exist, but has the potential to exist.

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Appendices

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Appendix A
Commercial Seed Sources

Commercial availability of native plant materials for use in establishment of diverse native plant communities is quite limited. Table A1 lists names, addresses and phone numbers for four of the major seed companies that market native seed for revegetating degraded Great Basin and Columbia Plateau rangelands. Listing of companies is for informational purposes only and does not imply an endorsement by the BLM.

Table A2 provides a list of species and varieties of native grass seed available from commercial sources. The source of ecotype is provided for each variety when identified in their respective catalogs. If source of the ecotype becomes an important factor, then few native seeds that are commercially available can be traced to collections within the Intermountain West.

Only eight of the species for which the source of the ecotype is identified, originated in the Intermountain West. For one species, Cover sheep fescue, the source population is Eurasian in origin.

The May 4, 1990 Final Draft of Research and Demonstration Program Plan to Restore and Maintain Native Plant Diversity on Deteriorated Rangelands in the Great Basin and Columbia Plateau contains lists-of priority plants to restore plant diversity on target areas in California, Idaho, Nevada, Oregon and Washington, and Utah. Forb and shrub species included in those lists which are commercially available are identified in Tables A3 and A4, respectively. If variety and source are provided by the companies, the information is included.

Table A1. Seed companies offering native seed.

Company Name	Address	Telephone/FAX
Bitterroot Native Growers, Inc.	445 Quast Lane Corvallis, MT 59828	(406) 961-4991/ (406) 961-4626
Davenport Seed Corporation	P.O. Box 187 Davenport, WA 99122	(509) 725-1235 (800) 828-8873/ (509) 725-7015
Granite Seed	1697 West 2100 North P.O. Box 177 Lehi, UT 84043	(801) 768-4422 (801) 531-1456/ (801) 768-3967
Sharp Bros. Seed Co.	Box 140 Healy, KS 67850	(316) 398-2231 (800) 4-NATIVE/ (316) 398-2220

Table A2. Species, varieties and commercial sources of native grass seed. For species with two scientific names, the upper scientific name represents the Hitchcock (1971) taxonomy, while the lower name represents the Barkworth and Dewey (1985) classification of the Triticeae.

Common name/ Latin name (Revised)+	Varieties (Source of ecotype)	Company Name
Thickspike wheatgrass/ *Agropyron dasystachyum* *(Elymus lanceolatus)*	Critana (Havre, MT) Davenport Sharp	Granite
Beardless bluebunch wheatgrass/ *Agropyron inerme* *(Pseudoroegneria spicata* subspp. *inermis)*	Whitmar (Whitman County, WA)*	Granite Davenport Sharp
Bluebunch wheatgrass/ *Agropyron spicatum* *(Pseudoroegneria spicata* subspp. *spicata)*	Secar (Lewiston, ID)*	Granite Davenport Sharp
	Goldar (?)	Davenport
Streambank wheatgrass/ *Agropyron riparium* *(Elymus lanceolatus)*	Sodar (Grant County, OR)*	Granite Davenport Sharp
Western wheatgrass/ *Agropyron smithii* *(Pascopyrum smithii)*	Arriba (Flagler, CO) Barton (Barton County, KS) Rosanna (Forsyth, MT) Rodan (?)	Granite Davenport Sharp
Davenport	Flintlock (?)	Sharp Sharp
Slender wheatgrass/ *Agropyron trachycaulum* *(Elymus trachycaulus)*	Primar (Beebe, MT) San Luis (Rio Grand County, Co)	Granite Davenport Sharp
	Pryor (Pryor Mtns., MT) Revenue (Saskatchewan, Canada)	Granite Davenport Sharp
California brome/ *Bromus carinatus*	Cucamonga (?)	Davenport
Rescuegrass *Bromus catharticus*	Prairie (?)	Davenport
Mountain brome/ *Bromus marginatus*	Bromar (Pullman, WA)*	Granite Davenport
Inland saltgrass/ *Distichlis stricta*		Granite Davenport

Table A2. Species, varieties and commercial sources of native grass seed. For species with two scientific names, the upper scientific name represents the Hitchcock (1971) taxonomy, while the lower name represents the Barkworth and Dewey (1985) classification of the Triticeae. (continued)

Common name/ Latin name (Revised)+	Varieties (Source of ecotype)	Company Name
Canada wildrye/ *Elymus canadensis*		Granite Davenport Sharp
Great Basin wildrye/ *Elymus cinereus* *(Leymus cinereus)*	Magnar (Saskatchewan, Canada) Arrowhead (?)	Granite Davenport Davenport
Creeping (or Beardless) wildrye/ *Elymus triticoides* *(Leymus triticoides)*	Shoshone (Riverton, WY)	Granite Davenport
Idaho fescue/ *Festuca idahoensis*	 Joseph (Idaho)*	Davenport Granite
Sheep fescue/ *Festuca ovina*	Covar (Turkey)	Granite Davenport
Prairie junegrass/ *Koeleria cristata*		Granite Davenport
Indian ricegrass/ *Oryzopsis hymenoides*	Nezpar (Whitebird, ID)* Paloma (Pueblo, CO)	Granite Davenport Sharp
Reed canarygrass/ *Phalaris arundinacea*	Loreed (?) Vantage (?) Loreed (?) Palaton (?) Venture (?)	Granite Davenport Sharp
Alkali bullrush/ *Phragmites communis*		Granite Davenport
Alpine bluegrass/ *Poa alpinum*		Granite Davenport
Big bluegrass/ *Poa ampla*	Sherman (Sherman County, OR)*	Granite Davenport Sharp
Canby bluegrass/ *Poa canbyi*	(Canbar (Blue Mtns., WA)*	Granite Davenport Sharp

Table A2. Species, varieties and commercial sources of native grass seed. For species with two scientific names, the upper scientific name represents the Hitchcock (1971) taxonomy, while the lower name represents the Barkworth and Dewey (1985) classification of the Triticeae. (continued)

Common name/ Latin name (Revised)+	Varieties (Source of ecotype)	Company Name
Sandberg bluegrass/ *Poa sandbergii* Sharp		Granite Davenport
Alkaligrass/ *Puccinellia distans*	Fults (?)	Davenport
Bottlebrush squirreltail/ *Sitanion hystrix* *(Elymus elymoides)*		Granite Davenport
Sand dropseed/ *Sporobolus cryptandrus*	 Salado (?) Saltalk (?)	Granite Sharp Davenport
Columbia needlegrass/ *Stipa columbiana* *(Stipa nelsonii)*		Granite Davenport
Needle and thread/ *Stipa comata*		Granite Davenport
Letterman needlegrass/ *Stipa lettermani*		Granite Davenport
Elk sedge/ *Carex geyeri*		Bitteroot

+Revised nomenclature based on Barkworth and Dewey (1985) Genomically based genera in the perennial Triticeae of North America: Identification and membership. Amer. J. Bot 72(5):767-776.

*Source of ecotype is from the Intermountain West.

Table A3. Commercially available forb species with potential for use in restoring plant diversity in Great Basin and Columbia Plateau rangelands.

Latin name (variety & source if provided)/ Common name	State for which listed +	Company
Achillea millefolium/ White Yarrow	Idaho Oregon & Wash	Granite
Balsamorhiza sagittata/ Arrowleaf balsam	California Nevada Oregon & Wash.	Granite Bitterroot
Epilobium angustifoliuml Fireflower	Idaho	Granite
Eriogonum umbelatum/ Sulfur flower	California Oregon & Wash.	Granite Bitterroot
Hedysarum boreale/ Northern sweetvetch	Idaho	Granite
Helianthus annuusl Annual sunflower	California	Granite
Linum lewisii (Appar, Black Hills, SD)/ Blue (Lewis) flax	Idaho Nevada Oregon & Wash. Utah	Granite
Lupinus arizonicus/ Desert lupine	Idaho	Granite
Lupinus caudatusl Tailcup lupine	Idaho	Granite
Lupinus perennis/ Wild lupine	Idaho	Granite
Lupinus sericeusl Silky lupine	Idaho	Granite Bitterroot
Lupinus succulentus/ Arroyo lupine	Idaho	Granite
Penstemon cyananthusl Wasatch penstemon	Idaho	Granite Bitterroot
Penstemon deustusl Hotrock penstemon	Idaho	Bitterroot
Penstemon eatonitii/ Firecracker penstemon	Idaho Oregon & Wash.	Granite Bitterroot

Table A3. Commercially available forb species with potential for use in restoring plant diversity in Great Basin and Columbia Plateau rangelands. (continued)

Latin name (variety & source if provided)/ Common name	State for which listed +	Company
Penstemon fruticosusl Shrubby penstemon	Idaho	Bitterroot
Penstemon palmeri (Cedar)/ Palmer penstemon	Idaho Oregon & Wash.	Granite Bitterroot
Sphaeralcea coccinea/ Scarlet globemallow	Idaho Nevada Utah	Granite
Sphaeralcea grossulariaefolia/ Gooseberry leaf globemallow	Idaho Utah	Granite

+Each state involved in the Vegetation Diversity Project identified priority plant species which were listed in: Vegetation Diversity Project: A Research and Demonstration Program Plan, May 1990, USDI-BLM, Oregon State Office.

Table A.4. Commercially available shrub species with potential for use in restoring plant diversity in Great Basin and Columbia Plateau rangelands.

Latin name/ Common name	State for which listed +	Company
Amelanchier alnifolia/ Serviceberry	California	Granite Bitterroot Davenport
Artemisia canal Silver sagebrush	Idaho	Granite Bitterroot Davenport
Artemisia nava/ Black sagebrush	Idaho	Granite Bitterroot Davenport
Artemisia tridentata/ Basin big sagebrush	Idaho Nevada Oregon & Wash.	Granite Bitterroot Davenport
Artemisia tridentata vaseyana/ Mountain big sagebrush	Idaho Oregon & Wash.	Granite Bitterroot Davenport

Table A.4. Commercially available shrub species with potential for use in restoring plant diversity in Great Basin and Columbia Plateau rangelands. (continued)

Latin name/ Common name	State for which listed +	Company
Artemisia tridentata wyomingensisl Wyoming big sagebrush	Idaho Nevada	Granite Bitterroot Davenport
Atriplex canescensl Fourwing saltbush	California Idaho Nevada Oregon & Wash. Utah	Granite Davenport
A triplex con fertifolia/ Shadscale	Idaho Nevada Utah	Granite Bitterroot Davenport
A triplex triden ta ta/ Trident saltbush	Idaho Davenport	Granite
Ceratoides (Eurotia) lana ta/ Winterfat or White sage	California Idaho Oregon & Wash. Utah	Granite Davenport
Cercocarpus ledifolius/ Curl-leaf mountain mahogany	California Oregon & Wash.	Granite Bitterroot Davenport
Chrysothamnus nauseosus/ Rubber rabbitbrush	Idaho	Granite Bitterroot Davenport
Chrysothamnus visicidiflorus/ Douglas rabbitbrush	California Idaho	Granite Davenport
Purshia tridentata/ Antelope bitterbrush	California Idaho Nevada Oregon & Wash.	Granite Bitterroot Davenport
Ribes aureum/ Golden currant	California	Granite Bitterroot Davenport
Shepherdia argentea/ Silver buff aloberry	California	Granite Bitterroot Davenport
Symphoricarpos albus/ Common snowberry	California	Granite Bitterroot Davenport

+Each state involved in the Vegetation Diversity Project identified priority plant species which were listed in: Vegetation Diversity Project: A Research and Demonstration Program Plan, May 1990, USDI-BLM, Oregon State Office.

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Appendix B
Cultural Practices

Wasser (1982) provides planting depth, rate, time, and related information for several of the priority species listed in the May 1990 Vegetation Diversity Project: A Research and Demonstration Program Plan. Available information is listed below.

Grasses

Agropyron dasystachyum (Elymus lanceolatus) Thickspike wheatgrass:

Drill seed 1/2 inch deep on fine-textured soils and up to 1 inch deep on coarser soils. Firming seedbeds before seeding is beneficial. Cover broadcasted seed shallowly with soil. Supplemental mulch and light irrigation on erosive and droughty sites ensure better establishment. About 20 to 25 PLS per square foot usually needed to obtain 1 to 2 plants per square foot. Fewer seeds with rhizomatous species may suffice if erosion and weed infestations are not serious hazards during longer establishment periods. Five to ten pounds PLS per acre are used for rangeland areas. Rate should be increased 100 percent for broadcasting with this species. About 50 PLS per foot of row were used in tests on surface-disturbed lands in western Colorado; similar amounts were used for harsh sites and south and west exposures. Drill seed either in early spring, late fall, or late summer-early fall (Aug.-Sept.) with ample moisture. Usually seed prior to the 2-month period with the most favorable moisture and temperature conditions for seedling establishment.

Agropyron smithii (Pascopyrum smithii) Western wheatgrass

Drill seed 1/2 to 1 inch deep on fine and medium-textured soils, respectively. Cover broadcasted seed shallowly with soil. Supplemental mulching and light irrigating aid stand establishment on arid, droughty, and erosive sites. About 20 to 25 PLS per unit area needed as seeding rate to establish one plant per unit area under moderately favorable nonirrigated conditions. Recommended drill seeding rates: 5 to 15 pounds PLS per acre for semiarid to subhumid areas. Increase rates 50 to 100 percent for broadcasting, quicker and denser cover, or for harsher south and west-facing sites. Seed before or very early in the 2-month period having the most favorable conditions for rapid germination and seedling growth: early spring, late fall; late summer to early fall (Aug. or Sept.); or June 15 to July 15 (only in Southwestern pine and pinyon-juniper zones).

Agropyron spicatum (Pseudoroegneria spicata) Bluebunch wheatgrass

Drill seed 1/4 inch, 1/2 inch, and 3/4 inch deep on clayey, loamy, and sandy soils, respectively. Cover broadcasted seed with soil to similar depths. Drill seeding rates vary from 5 to 10 pounds PLS per acre for rangeland revegetation purposes. Fifty to 100 percent more seed should be used for broadcasting and for harsh and south and west-facing sites. Seed before or very early in the 2-month period most favorable for seedling establishment; usually either early spring or late fall, but also possible in early fall (during August and Sept.) in areas with good fall moisture or on summer-fallowed fields.

Bromus marginatus Mountain brome

Drill seed about 1/2, 1, or 1 1/2 inches deep on finer, medium or coarse textured soils. Commonly seeded at 8 to 12 pounds PLS per acre for rangeland purposes; rate may be increased on disturbed soils and on harsh or eroding surfaces. Supplemental mulch aids soil stabilization and stand establishment on steep and erosive sites. Seed in late fall or as early in summer as possible in higher mountains.

Elymus cinereus (Leymus cinereus) Great Basin wildrye

Seed at 1 inch depth, drill seed 20 PLS per square foot (5 pounds PLS per acre) for dense pasture swards or use half as much seed when drilled early spring in furrows or corrugations on spring-flooded sites. Seed late fall or as early as possible in summer in mountain sites.

Festuca idahoensis Idaho fescue

Seed 1/4, 1/2, or 3/4 inches deep on fine, medium, or coarse-textured soils, respectively. Better stands obtained on prefirmed seedbeds. Drill a minimum of 15 to 25 PLS per square foot (2 to 3 pounds PLS per acre) for minimal satisfactory stands on rangelands. Increase rate 50 to 100 percent for harsh sites; south, west, or steep exposures; poorer seedbeds; and when broadcasting. May be seeded directly in nonvolunteering grain stubble or in alternate rows with wheat or rye; supplemental mulch may be added for steep slopes and highly erosive sites. Seeding time varies regionally and altitudinally: early spring at lower altitudes with reliable moisture; late fall with uncertain moisture and at lower mountain elevations; or in spring or very early summer, as early as possible, at higher mountain elevations.

Hilaria jamesii Galleta

Drill seed, in special drill equipped to handle chaffy seed, at 1/2 inch depth on fine-textured soils and moister seedbeds and up to 1 inch deep on coarser soils and drier seedbeds. May broadcast seed, but cover with soil to similar depths. Seeding in furrows, basins, and pits and using deep furrow type drills contribute to better stand establishment on more arid and finer textured seedbeds. Supplemental mulching plus light irrigations is the most reliable method of obtaining satisfactory stands. Plant 20 to 30 PLS per square foot for rangelands stands or 40 to 60 PLS per linear foot of row for disturbed land stabilization. Plant before or early in a 2-month period with most favorable conditions for rapid germination and seedling establishment; often June 15 to July 15 in northern Arizona and New Mexico.

Oryzopsis hymenoides Indian ricegrass

Drill seed 1 1/2 to 3 inches deep on medium to coarse-textured soils. Seeds emerge well from 4 inch depths in sand. Similar soil coverings needed for broadcast seedlings. Drill 20 to 25 PLS per square foot for rangeland purposes; double the seeding rate when broadcasting and for critical area stabilization purposes. Seed into nonvolunteering crop stubble seeded in 18-inch drill rows or closer in semiarid or wind-erosion areas. Still higher rates of seeding, supplemental mulching, and light irrigation may be necessary for good soil stabilization of disturbed sites. Generally seed before the 2-month period with most favorable conditions for rapid germination and seeding growth: late fall with high dormancy seed; early spring, early fall, or June 15 to July 15, according to regionally reliable moisture, with low dormancy seed. Dormancy overcome by using older seed, acid-bleached seed, or planting seed in fall to overwinter in soil.

Poa amp/a Big bluegrass

Drill seed about 1/2 inch deep for medium-textured soils with average moisture conditions or 1/4 inch shallower or deeper for finer and moister or for coarser and drier soils, respectively. Cover broadcasted seed with soil to a similar depth. Drill 3 to 5 pounds PLS per acre for minimal to moderate stand densities on semiarid to average moisture range sites seeded for pasturage and cover. Increase seeding rates 50 to 100 percent for broadcasting; for harsher, drier, and erosive sites; and for quicker and denser cover. Seed before or very early during the 2-month period with most favorable conditions for rapid germination and seedling growth: early spring; late summer; late fall; or as early as possible in summer for higher mountain sites.

Poa sandbergii (Poa secunda) Sandberg bluegrass

Drill seed on well-prepared and firmed seedbeds at 1/4 to 1/2 inch depths. Drill 30 to 40 PLS per square foot for rangeland purposes. Double seeding rate when broadcasting; for harsh, dry, and erosive sites; and for higher density cover. Seed areas before the 2-month period most favorable for rapid germination and seedling growth. Late fall suggested for Pacific Northwest and Great Basin states.

Forbs

Achillea millefolium Common (White) yarrow

Drill about 1/4 inch deep, or broadcast and cover to similar depth with soil, or cultipack. Drill 40 to 60 PLS per square foot (1/2 pounds PLS per acre) for pure stands under ideal moisture and soil conditions; double the rate when broadcasting and for harsh, erosive, and south- or west-facing sites. Reduce rate to proportion desired in mixtures. Seed at optimum date for primary species when in mixtures; preferably before the moistest growing season; usually early spring, late summer, or late fall. Species can be transplanted by sodpieces for critical area stabilization, such as gullies.

Balsamorhiza sagittata Arrowleaf Balsamroot

Drill seed 1/2 to 1 inch deep on medium and coarse-textured soils, respectively; vary depths similarly for moist and drier soil condition, respectively. Drill in either desired or original species composition percentages of a full stand rate of 20 PLS per square foot (10 to 20 percent recommended), using seed subjected to 2 months cold-moist stratification where 3 months continuous snow cover not assured on site after late fall seedings. These stratified seeds can be seeded very early, or as early as possible, in spring.

Hedysarum boreale Northern sweetvetch

Drill seed 1/2 inch deep on loam soils, up to 3/4 inch deep in drier and coarser soils, and 1/4 inch deep on finer textured and moister soils. Rates of 1/2 pound per acre drilled or 1 pound per acre broadcasted are recommended in seeding mixtures for sandy aspects of mountain brushlands in Utah. Planting in early spring or late fall advocated, late fall planting provides natural stratification. Inoculate seed with specific Rhizobium strain for nitrogen-fixation just before planting. Plants experimentally stimulated in soil infested with *Glomus fasciculatus,* a mycorrhizal symbiont.

Linum lewisii Lewis flax

Plant seed 1/4 to 3/4 inch deep or broadcast and cover with soil to similar depth. Adapt seeding rate to desired composition in seeding mixture, usually no more than 5 to 10 percent of a full stand seeding rate of 20 to 30 PLS per square foot (about 3 to 4 pounds PLS per acre) for semiarid zones. Increase rates 50 to 100 percent for humid zones, broadcasting, and for harsh sites, especially those on erosive soils, steep slopes, and south and west exposures. Plant at time optimal for primary species in seeding mixtures, preferably before the most humid growing season. Plant the species alone either late fall of seed-harvest year, the following spring, or the second fall; tests indicate latter date results in greater emergence.

Sphaeralcea grossulariaefolia Gooseberry globemallow

Plant seed less than 1 inch deep, varying with soil texture, moisture, and firmness and quality of seedbed. Plant only about 10 percent of this species in seeding mixtures or use about 1/4 pound PLS per acre. Fall and winter planting dates preferred to take advantage of late winter-early spring moisture and to provide a prechilling seed treatment.

Shrubs

Amelanchier alnifolia Saskatoon serviceberry

Plant seeds 1/4 inch deep. Nurserymen seed this species at a rate of 25 PLS per foot of row. Reduce seeding rate to obtain desired or original composition on sites being restored or improved. Only 1/2 to 1 pound per acre recommended in game range restoration mixtures. Plant unstratified seed in late fall and moist prechilled seed in spring. Transplants or container stock should be planted as early as possible in spring. Moist soil, mulch, and partial shade enhance nursery propagation. Readily propagated in greenhouse from softwood and root cuttings; stands can be established by transplanting seedlings or nursery stock. Using older nursery stock may be advantageous on difficult sites. Bare-rooted stock survived better than container stock in pine zone in South Dakota.

Artemisia cana Silver sagebrush

Plant seed on the surface or very shallowly; better germination reported with light and at temperatures between 50° and 86°F. Plant 10 to 20 PLS per square foot (0.5 to 1.0 pound PLS per acre) for full stands. Species often seeded at reduced rates approximating original composition on sites; e.g., using 0.10 pound PLS per acre. Rates should be doubled or further increased for critical areas, steep slopes, and eroding surfaces. Because of tolerance to broad temperature range for germination, amenable to seeding almost any time of the year when there is adequate surface soil moisture, such as fall, early spring, spring, or summer. Hardwood cuttings, cultured in greenhouse and hardened before out-planting on surface mined soils, gave better stands and survival than direct seeding in Wyoming-Colorado investigations and were more tolerant than other species to wildlife browsing.

Artemisia nova Black sagebrush

Plant achenes 1/4 inch deep. About 100 PLS per square foot used in nurseries to obtain about 50 seedlings per square foot in optimizing limited space and intensive culture; 1 to 2 PLS per square foot should prove an adequate rate on rangelands under ideal growing conditions. Comparing planting site conditions and survival expectancy with that ideal standard suggests that 10 to 20 PLS per square foot (1/2 to 1 pound PLS per acre) might be adequate drill rates for full stands on average rangeland sites. Higher rates needed when broadcasting and when seeding severe, erosive, and critical sites. Species more commonly used as minor element in seed mixtures for range revegetation, partly due to limited seed supply. Plant either in late fall and winter or use seed pretreated to enhance germination (i.e. placed in moist blotters at 32° to 38°F for 10 days) in spring.

Artemisia tridentata Big sagebrush

Either broadcast seed on the surface or plant at very shallow depth of about 1/4 inch. Light favors germination of basin-form, and seed will not emerge from 1 inch depths. Limited benefit of light noted with other two subspecies. One-forth to 1/2 pound per acre or double these rates recommended for drilling and broadcasting seed in mixtures on sagebrush-adapted but depleted Utah game ranges. Plant either in spring, fall, or winter. Moist chilling seed treatment may be of benefit when planting the spring after seed harvest.

Atriplex canescens Fourwing saltbush

Plant seed 1/2 to 3/4 inch deep in well-prepared seedbeds; use shallower depth with moist and finer textured soils; use the deeper placement for dry, loose, and coarse-textured soils. Mulching usually improves seedling emergence and survival. Seed 4 to 8 pounds per acre of dewinged seed and 8 to 15 pounds of winged seed for pure stands in favorable to less favorable habitats or site conditions and when planting or broadcasting, respectively. Reduce rate to desired or original fraction of the cover on planting sites when seeding in mixtures; 1/2 to 5 pounds per acre rates used as a component in 10 to 30 pounds per acre total seedings in Utah game range restorations, the higher rates in blackbrush type and when broadcasting, 1/2 to 2 pounds per acre rates more commonly used on shadscale saltbush, black greasewood, big sagebrush, mountain brush, and juniper-pinyon types. Spring or midsummer seedings generally more successful than fall seedings in the Southwest. Often seeded in mixtures sown in late fall or winter in Utah. Transplanting is an effective method of establishing stands on small critical areas. Transplanting is done in spring, with damp soil conditions, either by hand in prepared seedbed or in water-concentrating furrows or basins, or by using scalper and transplanter, carefully hand-fed, keeping stock moist and avoiding "J-roots".

Ceratoides (Eurotia) lanata Winterfat (White sage)

Plant seed less than 1/2 inch deep. They can be broadcast on surface of saturated soils, but usually better results obtained by planting 1/16 to 1/4 inch deep and covering or pressing broadcasted seed in soil to similar depths. Firming seedbed below seed depth improves emergence, and mulch aids natural establishment. Species usually only planted in mixtures with rates of 1/2 to 1 1/2 pounds per acre drilled or 1 1/2 to 3 pounds per acre broadcasted in total seed mixes of 10 to 20 pounds per acre. Recommend trying 15 to 20 PLS per square foot (about 5 to 7 pounds PLS per acre) drill rates for full stands; however, usually advantageous to seed with vigorous adapted grasses where annual weeds, such as cheatgrass brome *(Bromus tectorum)* and halogeton *(Halogeton glomeratus),* threaten. Best season of planting unknown; late fall, winter, and spring seedings used or recommended; usually better to seed before the moistest growing season, provided surface soils not saturated more than week or two. Some propagating success reported using stem cuttings in Nevada; practice probably useful for propagating superior selections.

Chysothamnus nauseosus Rubber rabbitbrush

Best planting depth unknown; use gardener's rule of 2 to 4 times the largest seed diameter, or about 1/2 to 1 inch deep. On game ranges direct seedings are made in fall or winter in Utah, and roadside seedings are made in November in Nevada. Since natural germination occurs from March to June, pretreating the seed (store wet for 1 month at 39°F to enhance germination) and seeding early in March may be a safer seeding time. No critical tests of optimum seeding rates appear in print. Rates of 1/2 pound per acre (drilled) and 1 pound per acre (broadcasted) are used in complex game range revegetation mixtures. Good stands were reported from transplanting 3 to 5-month old seedlings in early spring in Utah and some establishment success was reported with aerial seeding.

Chysothamnus viscidiflorus Douglas rabbitbrush

Plant seed about 1/4 inch deep or two to four times seed diameter. Best rate of seeding and optimal depth not known. Rabbitbrush was drilled at 1/4 pound per acre and broadcasted at 1/2 pound per acre in complex game range seeding mixtures in Utah. Game range seedings are made in late fall and winter. Germination studies indicate it can be seeded "anytime after harvest through the second fall with good germination results". Good success from transplanting seedlings or wildings were reported from Utah.

Purshia tridentata Antelope bitterbrush

Drill seed in a clean, firm seedbed with a rangeland drill about 1 inch deep, adapt depth slightly deeper or shallower according to moisture, texture, and seedbed firmness. Cover broadcasted seed with soil to similar depth. Optimal rates for pure seedings apparently not critically tested, probably because most seedings are made in mixtures to avoid waiting 5 to 10 years for bitterbrush to develop usable forage supplies. Rates of 1/2 to 1 pound per acre, 1 to 2 pounds per acre, and 2 to 3 pounds per acre, drilled and broadcasted, are prescribed in game range restoration in Utah. Seed are planted most commonly in late fall or early winter to accomplish a natural stratification over winter but treated seed can be planted in spring or later with adequate moisture. Limited transplanting of nursery grown seedlings or container stock has been done, usually in spring.

Ribes aureum Golden currant

Nursery seedlings are made 1/8 to 1/4 inch deep and mulched; rangeland seedings might be made at 1/2 inch depth in drier sites with better survival expected. Nurserymen seed at rate of 40 PLS per linear foot of row. Best rate on rangelands is not documented. Many seedings optionally include currant seed as minor component, perhaps at 1/2 to 1 pound per acre, in range seedings for game range restoration or controlling erosion. Fall preferred seeding time; stratified seed can be sown in spring. Areas also revegetated using nursery or container stock and rooted cuttings.

Shepherdia argentea Silver buffaloberry

In nursery practice, seeds are planted 1/4 inch deep and covered with up to 1 inch of mulch. This suggests that seed could be planted at depths up to 3/4 inch in coarse, dry, and loose soil (in fall under wildland conditions). About 50 percent seedling establishment is expected in nurseries while 5 to 15 percent establishment would be good survival from seeding under dryland field conditions. This species is used as a minor addition to game rangeland revegetation mixtures in Utah at unspecified rates. Similar species are added at 1 to 2 pounds per acre rates in total seeding mixtures of 10 to 30 pounds per acre. Seed can be sown in the fall or can be moist-prechilled ("stratified") for 3 months then sown in spring or later where late summer moisture is more reliable or where irrigation is available. Buffaloberry can be transplanted by digging root sprouts from wildings or from nursery-grown stock. Older stock is often used for landscaping; 2-year-old planting stock is used in reclaiming eastern coal minesoils.

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Appendix C
Seed Testing

The Seed Laboratory of the Crop and Soil Science Department at Oregon State University is able to provide seed testing service. In addition to the traditional seed potential tests of purity and germination potential, the Seed Lab provides the following tests:

a) Tetrazolium - A chemical test indicating seed viability by a staining process. Results are available as quickly as 24 hours.

b) X-ray - Empty, insect infested, and internal and external mechanical injury are some of the abnormalities evident by means of a radiograph (X-ray film).

c) Chromosome count - With the growing of polyploids, it becomes necessary to determine variety contamination by counting the number of chromosomes.

d) Moisture - High moisture and high temperatures are detrimental to seed viability. For storage (refer to Appendix D- Seed Storage) and shipping, it becomes important to know that the moisture content of the seed is at a safe level.

e) Seed Weight - Where space planting or high-cost seed is being used, it becomes desirable to know the weight per 1,000 seeds so that density of planting can be controlled.

f) Variety - Chemical and physical test for varieties are available to help maintain a high varietal purity level.

g) Endophyte - This staining process detects the presence of endophytic fungi in seed, seedling, and plant material.

At the minimum, purity and germination potential should be tested. Other testing will depend on specific circumstances.

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Appendix D
Seed Storage

One of the goals of the Vegetation Diversity Project is to develop an information base which will improve BLM's ability to re-establish and manage for native vegetation. Addressing this goal will require collection of native plant seeds from natural stands to provide plant materials necessary for research purposes. Since many species seldom produce viable seed, relatively long-term (two years or longer) storage of collections will be critical for maintaining seed stocks of native seeds for research purposes and for potential expansion.

Principles and Practices of Seed Storage by Justice and Bass (1978) provides a comprehensive coverage of seed storage. Storage temperature and seed moisture content are the most important factors affecting seed longevity, with seed moisture content usually more influential than temperature.

Research needs and time and labor constraints likely to affect the Vegetation Diversity Project dictate the probable need for long-term storage of seeds already collected by the Rangeland Resources Department and those which will presumably be collected throughout the duration of the project. Refrigerated, dehumidified storage is best suited for long-term holding of seeds. Under humidity conditions common to Corvallis through the winter months, controlled atmospheric storage conditions or sealed storage will be necessary to maintain seed viability. For safe, sealed storage for up to 3 to 5 years at ambient temperatures, seeds must be dried to between 5 and 8 percent moisture content before they are sealed in moistureproof containers. For longer storage, the moisture content must be reduced to between 2.5 and 5 percent before packaging (Justice and Bass 1978).

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Appendix E
Seed Treatment Studies

Indian ricegrass

Indian ricegrass seed is characterized by physiological and mechanical dormancy, but their relative importance is a characteristic of the seedlot rather than of the species as a whole. Seed age, genotype, and seed production and storage environments are important factors that affect dormancy among seedlots (Jones and Nielson 1992). The following excerpts of the literature review in the Jones and Nielson (1992) paper describe current knowledge of Indian ricegrass seed dormancy:

> "Seed dormancy is an important cause of the poor stand establishment that has limited use of Indian ricegrass. Mechanical dormancy, resulting from the exclusion of 0, by the indurate lemma and palea (Toole 1940) is more persistent than physiological dormancy (McDonald 1976). Physiological dormancy decreases over time, but storage at low humidity and temperature slows the process (Robertson 1976, McDonald and Khan 1977). Physiological dormancy is of less concern when fall seeding is practiced, as is common in the Intermountain region, because it can be broken by cool, moist field conditions (Stevens and Meyer 1990). ...Physiological dormancy has been reduced by aging seed (Rogler 1960), fall planting (Fendall 1966), prechilling (Toole 1940, Clark and Bass 1970), and application of growth regulators such as kinetin and gibberellic acid (Clark and Bass 1970, McDonald 1976, Young et al. 1985). Mechanical dormancy has been reduced by mechanical and acid scarification, but scarification increases germination at the expense of seed quality. Early workers (Stoddart and Wilkinson 1938) eliminated mechanical dormancy by manually dissecting the lemma and palea, but more recently mechanical scarification has been employed ."
>
> "Extensive research has been conducted on acid scarification (Stoddart and Wilkinson 1938, Plummer and Frischknecht 1952, McDonald 1976, Young et al. 1985). Seed damage during acid scarification can probably be reduced by adjusting length of treatment to seed size (Stoddart and Wilkinson 1938) or to lemma thickness (Zemetra and Cuany 1984)."
>
> "While germination of naked seed is considerably higher than seed with lemma and palea intact (Young and Evans 1984, Jones et al. 1988) naked seed are susceptible to fungal and bacterial disease. The disease resistance conferred by the lemma and palea has been attributed to phenolic compounds. McDonald (1976) successfully controlled disease in the laboratory with 40% maneb (manganese ethylenebisdithiocarbonate) applied as a dust or slurry. Poor field establishment of acid-scarified seed despite dusting was attributed to deterioration of the lemma and palea over winter (Zemetra et al. 1983). Lemmas and paleas of intact mechanically scarified seed may be more persistent over winter than those of acid-scarified seed. This suggests a possible advantage of mechanical over acid scarification for field establishment. ... Toole (1940) concluded acid scarification reduced physiological dormancy as well as mechanical dormancy because some scarified seedlots exhibited enhanced germination despite persistent lemmas and paleas. Griffith and Booth (1988) suggested loss of dormancy in recently harvested seed could be accelerated by scarification before storage. Shaw (1976) found that prechilling more effectively broke dormancy of naked seed than intact seed. These results suggest that breaking mechanical dormancy may accelerate the loss of physiological dormancy."

Winterfat (White sage)

Booth and Schuman (1983) conducted a series of studies to compare winter-fat establishment from whole fruits and from seed. Their studies demonstrated three important ways the whole fruit aids seedling establishment. First, the hairs of the bracts become embedded in the soil surface and restrain the fruit, thereby improving radicle penetration of the soil. Second, threshed seeds have been shown to have a significant population (up to 24%) of germinants which lack a positive geotropic response by the radicle. The geotropic deficiency found in threshed seed is apparently due to damage to the embryo rootcap during threshing. Third, a comparison of seedling vigor, as measured by radicle elongation of seedlings established from fruits and from seed, found radicle growth from fruits to be almost twice that of seedlings from seeds. The authors made the following recommendations for improving the planting success of winterfat:

1. Use good, large, healthy appearing fruits (and not threshed seed) which have been allowed to

afterripen at room temperature for 2 months before storage in a cold (0 to 4°C, 32 to 39°F), dry environment.

2. Broadcast the whole fruits. The seedbed must be rough, providing numerous places for the fruits to lodge - otherwise most of the fruits will be blown off the area being planted. In some instances a broadcast seeder, such as a Brillion Seeder, may effectively plant winterfat fruits at the required shallow (6.4 mm - 1/4 inch or less) depth.

3. If planting in an area of winter precipitation, plant as late in the fall as possible. A snow cover soon after planting will further reduce the amount of fruit lost due to the wind.

4. If working in an area which is likely to have a dry surface soil during winter, plant in the spring when the probability is greatest of having extended periods of soil moisture between field capacity and saturation. Also keep in mind that the larger the young plants are when hot weather 20 to 27°C (70 to 80°F) arrives, the better the survival.

5. A spring planting of fruits soaked for 48 hours at 0°C (32°F) followed by hand planting in moist soil, can be recommended as a technique to enhance establishment of a few plants which may serve as sources of fruits for later natural revegetation or as special area plantings. The soaked fruits must not dry before germination occurs.

In a later study, Booth (1992) concluded that imbibition temperature affects post-germination growth of winterfat. Successful germination, establishment, and survival of winterfat are better at 5°C compared to 15-20°C. Therefore, winterfat should be sown during those parts of the year when diaspores will imbibe at cool temperatures. Winterfat should be imbibed and held at 5°C for 4 days, then germinated at 15°C when testing germination.

Appendix F
Noxious Weeds

Idaho

Table F1. Idaho Department of Agriculture Designated Noxious Weeds.

Common Name	*Latin name*
Austrian field cress	*Rorippa austriaca*
Austrian pea weed or Swainsonpea	*Swainsona salsula*
Buffalo bur	*Solarium rostratum*
Camelthorn	*Alhagi camelorum*
Canada thistle	*Circium arvense*
common crupina	*Crupina vulgaris*
Dalmation toad flax	*Linaria da/matica*
diffuse knapweed	*Centaurea diffusa*
Dyers woad	*lsatis tinctoria*
field bindweed	*Convolvulus arvensis*
henbane	*Hyoscyamus niger*
jointed goatgrass	*Aegilops cylindrica*
leafy spurge	*Euphorbia esula*
loosestrife	*Lythrum salicaria*
musk or nodding thistle	*Carduus nutans*
perennial pepperweed	*Lepidium latifolium*
perennial sowthistle	*Sonchus arvensis*
poison hemlock	*Conium maculatum*
puncture vine	*Tribulus terrestris*
rush skeleton weed	*Chondrilla juncea*
Russian knapweed	*Centaurea repens*
Scotch thistle	*Onopordon acanthium*
silver-leaf nightshade	*Solanum elaeagnifolium*
skeletonleaf bursafe	*Franseria discolor*
spotted knapweed	*Centaurea maculosa*
Syrian bean caper	*Ygophyllum fabago*
tansy ragwort	*Senecio jacobaea*
white-top	*Cardaria draba*
wild carrot or Queen Anne's lace	*Daucus carota*
yellow starthistle	*Centaurea solstitialis*
yellow toad flax	*Linaria vulgaris*

Nevada

Table F2. Designated noxious weed for the state of Nevada

Common Name	Latin Name
Austrian fieldcress	*Rorippa austriaca*
Austrian peaweed	*Sphaerphysa* or *Swainsona salsula*
Camelthorn	*Alhagi camelorum*
Klamath weed	*Hypericum perforatum*
poison hemlock	*Conium maculatum*
water hemlock	*Cicuta* spp.
Carolina horse nettle	*Solanum carolinense*
white horse nettle	*Solanum elaeagnifolium*
diffuse knapweed	*Centaurea diffusa*
Russian knopweed	*Centaurea repens*
leafy spurge	*Euphorbia esula*
licorice	*Glycyrrhiza lepidora*
Mediterranean sage	*Salvia aethiopis*
Medusahead rye	*E/ymus* or *Taematherum caput-medusae*
puncture vine	*Tibulus tgerrestris*
perennial sorghum spp. including, but not limited to:	
Johnson grass	*Sorghum halepense*
Sorghum alum	
perennial sweet sudan	
Canada thistle	*Cirsium arvense*
musk thistle	*Carduus nutans*
Scotch thistle	*Onopordum acanthium*
sow thistle	*Sonchus arvenis*
Iberian starthistle	*Centaurea iberica*
purple starthistle	*Centaurea calcitrapa*
yellow starthistle	*Centaurea solstitialis*
dalmation toadflax	*Lionaria dalmatica*
whitetop or hoary cress	*Cardaria draba*
	Lepidium draba
	L. repens
	L . latifolium
	Hymenophysa pubesens

Oregon

The Oregon State Department of Agriculture has developed a three category Noxious Weed rating system.

(1) An "A" designated weed is a weed of known economic importance which occurs in the state in small enough infestations to make eradication/containment possible; or not known to occur, but its presence in neighboring states make future occurrence seem imminent (Table F.l).

Recommended Action: Infestations are subject to intensive control when and where found.

(2) A "B" designated weed is a weed of economic importance which is regionally abundant, but of limited distribution in other counties (Table F.2).

Recommended Action: Moderate to intensive control at the state or county level.

(3) A "T" designated weed is a noxious weed designated by the State Weed Board as a target weed species (Table F.3).

Recommended Action: The department will focus intensive control measures (Appendix Table F.3).

Table F3. "A" designated weeds as determined by the Oregon Department of Agriculture.

Common Name	***Latin Name***
Bearded creeper (Common crupina)	*Crupina vulgaris*
Camelthorn	*Alhagi camelorum*
Hydrilla	*Hydrilla verticillata*
Iberian star-thistle	*Centaurea iberica*
Matgrass	*Nardus stricta*
Purple starthistle	*Centaurea calcitrapa*
Silverleaf nightshade	*Solanum eleagnifolium*
Smooth cordgrass	*Spartina alterniflora*
Squarrose knapweed	*Centaurea virgata*
Whitestem distaff thistle	*Carthamus leaucocaulos*
Wooly distaff thistle	*Carthamus lanatus*

Table F4. "B" designated weeds as determined by the Oregon Department of Agriculture.*

Common Name	***Latin Name***
Austrian peaweed (Swainsonpea)	*Sphaerophysa salsula*
Buff alo burr	*Solanum rostratum*
Bull thistle	***Cirsium vulgare***
Canada thistle	***Cirsium arvense***
Dalmatian toadf lax	***Linaria dalmatica***
Diffuse knapweed	***Centaurea diffusa***
Dodder	***Cuscuta* spp.**
Dyer's Woad	***Isatis tinctoria***
Eurasian watermilfoil	*Myriophyllum spicatum*
Field bindweed	***Convolvulus arvensis***
French broom	*Cytisus monspessulanus*
Giant horsetail	*Equisetum telmateia*
Gorse	*Ulex europaeus*
Halogeton	***Halogeton glomeratus***
Italian thistle	***Carduus pycnocephalus***
Japanese knotweed (Fleece flower)	*Polygonum cuspidatum*
Johnsongrass	*Sorghum halepense*
Jointed goatgrass	*Aegilops cylindrica*
Kochia	***Kochia scoparia***
Leafy spurge	***Euphorbia esula***
Meadow knapweed	*Centaurea jacea x nigra*
Mediterranean sage	***Salvia aethiopis***
Medusahead rye	***Taeniatherum caput-medusae***
Milkthistle	*Silybum marianum*
Musk thistle	***Carduus nutans***
Perennial pepperweed	*Lepidium latifolium*

Table F4. "B" designated weeds as determined by the Oregon Department of Agriculture.*

Common Name	*Latin Name*
Poison hemlock	*Conium maculatum*
Puncturevine	***Tribulus terrestris***
Purple loosestrife	***Lythrum salicaria***
Quackgrass	*Agropyron repens*
Ragweed	*Ambrosia arteimisiifolia*
Rush skeletonweed	***Chondrilla juncea***
Russian knapweed	***Acroptilon repens***
Scotch broom	*Cytisus scoparius*
Scotch thistle	***Onopordum acanthium***
Slender-flowered thistle	*Carduus tenuiflorus*
South American waterweed (Elodea)	*Eloda dense*
Spikeweed	***Hemizonia pungens***
Spiny cocklebur	*Xanthium spinosum*
Spotted knapweed	***Centaurea maculosa***
St. Johnswort (Klamath weed)	***Hypericum perforatum***
Tansy ragwort	***Senecio jacobaea***
Velvetleaf	***Abutilon theophrasti***
Western horsetail	***Equisetum arvense***
White top (Hoary Cress)	***Cardaria* spp.**
Wild proso millet	*Panicum miliaceum*
Yellow nutsedge	*Cyperus esculentus*
Yellow toadflax	***Linaria vulgaris***

*Species highlighted in bold type are likely to occur in eastern Oregon rangeland system.

Table F5. The ODA Target "T" List.*

Common Name	*Latin Name*
Bearded creeper (Common crupina)	*Crupina vulgaris*
Gorse	*Ulex europaeus*
Leafy spurge	***Euphorbia esula***
Rush skeletonweed	***Chondrilla juncea***
Squarrose knapweed	***Centaurea virgata***
Tansy ragwort	***Senecio jacobaea***
Wooly distaff thistle	*Carthumus lanatus*
Yellow stat-thistle	***Centaurea solstitialis***

*Species highlighted in bold type are likely to occur in eastern Oregon rangeland system.

Utah

In Utah, county weed departments, private property owners, farmers, ranchers, and state and federal agencies are encouraged to be aware of the presence of new and invading weeds on their property. The State Department of Agriculture encourages all property owners to develop and implement control measures that will control and prevent the spread of these invading weeds. It is the desire of the Department to prevent these invading weeds from reaching a level of infestation that would require them to be declared a State Noxious Weed. Counties where known infestations of these weeds occur are encouraged to declare these weeds as County Noxious Weeds, and to develop and implement control programs against these weeds.

Table F6. Officially designated and published noxious weeds for the State of Utah, as per the authority vested in the Commissioner of Agriculture under Section 4-17-3, Utah Noxious Weed Act:

Common Name	*Latin Name*
Bermudagrass *	*Cynodon dactylon* (L.) Pers.
Bindweed (Wild Morning-glory)	Convolvulus spp.
Broad-leaved Peppergrass (Tall Whitetip)	*Lepidium latifolium* L.
Canada Thistle	*Cirsium arvense* (L.) Scop.
Diffuse Knapweed	*Centaurea diffusa* Lam.
Dyers Woad	*Isatis tinctoria* L.
Perennial Sorghum spp., including but not limited to:	
Johnson grass, and	*Sorghum halepense* (L.) Pers.
Sorghum Almum	*Sorghum almum, parodi*
Leafy Spurge	*Euphorbia esula* L.
Medusahead	*Taeniatherum caput-medusae* (L.) Nevski
Musk Thistle	*Carduus nutans* L.
Quackgrass	*Agropyron repens* (L.) Beauv.
Russian Knapweed	*Centaurea repens* L.
Scotch Thistle	*Onopordium acanthium* L.
Spotted Knapweed	*Centaurea maculosa* Lam.S
quarrose Knapweed	*Centaurea squarrosa* Roth
Whitetop	*Cardaria* spp.
Yellow Starthistle	*Centaurea solstitialis* L.

• Bermudagrass shall not be a noxious weed in Washington County and shall not be subject to provisions of the Utah Noxious Weed Law within the boundaries of that county. It shall be a noxious weed throughout all other areas of the state of Utah and shall be subject to laws therein.

Table F7. Weeds designated and published in Utah as New and Invading Weeds:

Common Name	*Latin Name*
Black Henbane	*Hyoscyamus niger*
Dalmation toadflax	*Linaria dalmatica*
Goatsrue	*Galega officinalis*
Jointed goatgrass	*Aegilops cylindrica*
Water hemlock	*Cicuta douglasii*
Poison hemlock	*Conium maculatum*
Yellow nutsedge	*Cyperus esculentus*
Wild proso millet	*Panicum miliaceum*
Silverleaf nightshade	*Solanum elaeagnifolium*
Velvetleaf	*Abutilon theorphrasti*

Washington

Washington has three class system for classification of noxious weeds. Class A noxious weeds (Table F8) are those noxious weeds not native to the state that are of limited distribution or are unrecorded in the state and whose introduction to the state of Washington was not intentional, or whose intentional introduction poses a serious threat to the state for which no containment is assured by the owner. Class B noxious weeds (Table F9) are those noxious weeds not native to the state that are of limited distribution or are unrecorded in a region of the state and that pose a serious threat to the region. "Class B designate" means those Class B noxious weeds whose populations in a region or area are such that all seed production can be prevented within a calendar year. Class C are any other noxious weeds (Table F10).

Table F8. Class A noxious weeds in Washington.

Common Name	Latin Name
Syrian bean-caper	*Zygophyllum fabago*
Texas blueweed	*Helianthus ciliaris*
buffalobur	*Solanum rostratum*
wild chervil	*Anthricus sylvestris*
salt meadow cordgrass	*Spartina patens*
common crupina	*Crupina vulgaris*
wild four o'clock	*Mirabilis myctaginea*
mouseear hawkweed	*Hieracium pilosella*
hedgeparsley	*Torilis arvensis*
giant hogweed	*Heracleum mantegazzianum*
johnsongrass	*Sorghum halepense*
bighead knapweed	*Centaurea macrocephala*
Vochin knapweed	*Centaurea nigrescens*
Venice mallow	*Hibiscus trionum*
silverleaf nightshade	*Solanum elaeagnifolium*
peganum	*Peganum harmala*
Mediterranean sage	*Salvia aethiopsis*
dwarf snapdragon	*Chaenorrhinum minus*
purple starthistle	*Centaurea calcitrapa*
talian thistle	*Carduus pycnocephalus*
milk thistle	*Silybum marianum*
slenderflower thistle	*Carduus tenuiflorus*
unicorn-plant	*Proboscidea louisianica*
velvetleaf	*Abutilon theophrasti*
dyers woad	*Isatis tinctoria*

Table F9. Class B noxious weeds are designated as noxious weeds only in specific areas of Washington state. Species listed here are Class B designates in some portion of eastern Washington, but may be confined to a small area. For specific location information, refer to Chapter 16-750 WAS 'State Noxious Weed List and Schedule of Monetary Penalties."

Common Name	Latin Name
blackgrass	*Alopecurus myosuroides*
blueweed	*Echium vulgare*
Scotch broom	*Cytisus scoparius*
white bryony	*Bryonia alba*
common bugloss	*Anchusa officinalis*

Table F9. Class B noxious weeds are designated as noxious weeds only in specific areas of Washington state. Species listed here are Class B designates in some portion of eastern Washington, but may be confined to a small area. For specific location information, refer to Chapter 16-750 WAS "State Noxious Weed List and Schedule of Monetary Penalties."

Common Name	*Latin Name*
annual bugloss	*Anchusa arvensis*
camelthorn	*Alhagi pseudalhagi*
common catsear	*Hypochaeris radicata*
smooth cordgrass	*Spartina alterniflora*
common cordgrass	*Spartina anglica*
oxeye daisy	*Chrysanthemum leucanthemum*
hybrid deadnettle	*Lamium hybridum*
hedgehog dogtailgrass	*Cynosurus echinatus*
Austrian fieldcress	*Rorippa austriaca*
gorse	*Ulex europaeus*
orange hawkweed	*Hieracium aurantiacum*
yellow hawkweed	*Hieracium pratense*
indigobush	*Amorpha fruticosa*
black knapweed	*Centaurea nigra*
brown knapweed	*Centaurea jacea*
diffuse knapweed	*Centaurea diffusa*
meadow knapweed	*Centaurea jacea x nigra*
Russian knapweed	*Acroptilon repens*
spotted knapweed	*Centaurea maculosa*
lepyrodiclis	*Lepyrodiclis holsteoides*
garden loosestrife	*Lysimachia vulgaris*
purple loosestrife	*Lythrum salicaria*
wand loosestrife	*Lythrum virgatum*
yellow nutsedge	*Cyperus esculentus*
hawkweed oxtongue	*Picris hieracioides*
perennial peppetweed	*Lepidium latifolium*
tansy ragwort	*Senecio jacobaea*
longspine sandbur	*Cenchrus longispinus*
rush skeletonweed	*Chondrilla juncea*
perennial sowthistle	*Sonchus arvensis atvensis*
leafy spurge	*Euphorbia esula*
yellow star-thistle	*Centaurea solstitialis*
Swainsonpea	*Sphaerophysa salsula*
musk thistle	*Carduus nutans*
plumeless thistle	*Carduus acanthoides*
Scotch thistle	*Onopordum acanthium*
Dalmatian toadflax	*Linaria genistifolia spp dalmatica*
Eurasian watermilfoil	*Myriophyllum spicatum*

Table F10. State of Washington Class C noxious weed list.

Common Name	*Latin Name*
babysbreath	*Gypsophila paniculata*
field bindweed	*Convolvulus arvensis*
wild carrot	*Daucus carota*
conical catchfly	*Silene conoidea*
spiny cocklebur	*Xanthium spinosum*
hoary cress	*Cardaria draba*
smothseed alfalfa dodder	*Cuscuta approximata*
garden rocket	*Eruca vesicaria* spp. *sativa*
black henbane	*Hyoscyamun niger*
houndstongue	*Cynoglossum officinale*
kochia	*Kochia scoparia*
scentless mayweed	*Ma tricaria maritima* var. *agrestis*
common mullein	*Verbascum thapsus*
bitter nightshade	*Cloanum dulcamara*
poison-hemlock	*Conium maculatum*
puncturevine	*Tribulus terres tris*
cereal rye	*Secale cereale*
spikeweed	*Hemizonia pungens*
common St. Johnswort	*Hypericum perforatum*
common tansy	*Tanacetum vulgare*
yellow toadflax	*Linaria vulgaris*
bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
hairy whitetop	*Cardaria pubescens*
absinth wormwood	*Artemisia absenthium*

Appendix G
Concerns of Land and Resource Managers

State Offices

Variation in priority of communities to be addressed by the Vegetation Diversity Project reflects the relative differences among the states in prominence of salt desert shrub versus sagebrush steppe communities.

Idaho

In Idaho, most rehabilitation efforts occur in the Wyoming big sagebrush 8-14” precipitation zone. Frequent fires and resulting cheatgrass monocultures are the primary problem.

Research needs include identifying a variety of native species for revegetation use. Compatible species mixtures would be desirable to provide weed suppression through multiple niche occupancy. Squirreltail was mentioned as a native grass capable of competing with cheatgrass and medusahead and initiating succession to a desired native plant community. Seed sources for and variation among ecotypes of squirreltail are a problem. Other native perennial grasses mentioned were Thurber’s needlegrass which is competitive but grazing sensitive and Sandberg bluegrass. Bluebunch wheatgrass has been studied in the Greenstripping Project and offers potential for revegetation work. Additional species are needed.

Among characteristics to be considered in species for revegetation, fire tolerance is critical and herbicide tolerance would be desirable.

Follow-up management of rehabilitation efforts needs to be researched. Proper grazing management in particular needs to be researched and developed.

Special status plants identified for research efforts include *Happlopappus raddiatus* (Snake River goldenweed), *Lepidium* (a biennial on the Snake River Plain), and *Astragalus* as a genus which includes many species and may have wide application for a number of special status plants. Knowledge of life histories and propagation techniques are needed.

Collaboration with the Intermountain Greenstripping Rehabilitation and Research Project in Idaho may provide an opportunity to evaluate native species for competitiveness and fire tolerance.

Nevada

Salt Desert Shrub, Wyoming big sagebrush and Mountain big sagebrush are major community types in Nevada. Of these, Wyoming big sagebrush was considered the number one priority in terms of research needs for both reestablishment and maintenance of native plant communities primarily because of fire frequency. Salt Desert Shrub communities don’t burn frequently because of low fuel load characteristics. It was felt that Mountain big sagebrush communities generally have high enough precipitation so that standard revegetation practices would suffice.

A primary management concern in Nevada is the amount of large monotypic expanses of cheatgrass. Of growing concern is the spread of medusahead into areas previously dominated by cheatgrass. Medusahead was thought to be confined to clay soil sites. However, it has recently been noted as spreading onto loamy soil sites as it replaces cheatgrass following frequent burning.

Squirreltail has been competitive with both cheatgrass and medusahead. Squirreltail is a native, perennial grass that appears to be capable of withstanding a higher amount of grazing and of competition from exotic plants than many native grasses in the sagebrush steppe. Managers have observed squirreltail apparently establishing itself in medusahead dominated sites. Replacement of cheatgrass and medusahead with squirreltail may be a means of initiating successional reestablishment of perennial native grasses in areas now dominated by exotic annuals. Seed sources for squirreltail are needed. Knowledge of ecotypic characteristics is also needed.

Juniper encroachment was also mentioned as a concern for Nevada. Fire at early stages of development will often control juniper but, has a negative impact on other wildlife browse species. A need for fire tolerant plants and for native species in general was mentioned from a management perspective.

Oregon and Washington

Appendix C in the May 1990 “Vegetation Diversity Project: A Research and Demonstration Program Plan” identifies the site priorities defined by the five eastern Washington and Oregon Districts during meetings between Vegetation Diversity Project and District personnel. Generally, "loamy" range sites receiving 7-12 inches of annual precipitation with Wyoming big sagebrush as the dominant shrub species were the highest priority sites.

All Districts identified the need for sources of native seed, information on ecotypic variability, any information on native forbs, seeding techniques and post-treatment management requirements.

Special status plant research needs included seedbank inventory methods, basic life history information, and a focus on genera such as *Lupine, Eriogonum, Trifolium* and *Astragalus* as opposed to individual species. Appropriate monitoring techniques was a consistently high priority for special status plant programs.

Each of the Districts identified several other research priorities, several of which are pertinent to the Vegetation Diversity Project.

Burns

Seeding techniques to enhance establishment and plant materials screening/development (native species) were identified as the primary priorities for the Vegetation Diversity Project.

Juniper expansion was identified as a major concern. If, when and how to treat it are questions needing answers.

Weeds identified as problems include cheatgrass, medusahead which is expanding, and spotted and diffuse knapweeds which are beginning to encroach.

An Environmental Assessment (EA) has been completed for a proposed burn and reseeding effort on a 2200 acre area on Coyote Rim near Silver Lake. The area is dominated by Wyoming big sagebrush. Reseeding with bluebunch wheatgrass, squirreltail, Thurber's needlegrass, and needle-and-thread has been suggested. Funding is lacking for the project. Such a project might be useful as a demonstration.

Lakeview

Lakeview personnel considered maintenance of sites with existing positive diversity as the highest priority. Establishment of native plant materials on degraded sites was second followed by plant materials identification/development.

Additional questions and concerns included: A quantifiable method of determining adequacy of vegetation diversity is desired. What should it be, how is it maintained where it exists, and when is treatment needed to enhance diversity? An Ecological Site Inventory (ESI) team is currently operating in the District. District personnel questioned whether or not ESI is appropriate, and, if so, how the information can be used. Causes of juniper encroachment were questioned. Should control be attempted? If so, how? Sagegrouse decline is a concern. Questions were raised about management implications such as a relationship to grazing, fire, or conversion of lake beds to waterholes.

More information about the potential use of fire as a management tool is desired. Lakeview District has used prescribed fire followed by direct bitterbrush seeding.

An 85 acre enclosure with 5 acre replicated plots of native seedings has been established. It is being evaluated by District Range personnel and Squaw Butte researchers.

Spokane

The communities most in need of research involve the Channel scablands, Wyoming big sagebrush/bluebunch wheatgrass sites. Desirable species of interest include bluebunch wheatgrass, needle-and-thread, Sandberg bluegrass, Idaho fescue, Wyoming big sagebrush, bitterbrush, and arrowleaf balsamroot. These sites are typically in the 9-12" precipitation zone and have light sandy soils.

Cheatgrass is the number one weed problem with diffuse knapweed in the shrub-steppe and spotted knapweed in transition to forest areas becoming noticeable.

A skeleton weed project is underway in the Juniper Dunes Wilderness Area. Individual skeleton weed plants have been located and mapped with a Trimble Polycorder GPS system. Treatment with Tordon (picloram) was scheduled for May. Follow-up monitoring will determine efficacy of the program.

A special status plant restoration plan will be implemented in Lincoln County for *Polemonium pectinatum.*

Prineville

Juniper encroachment, sagegrouse habitat needs, and reclamation of dense sagebrush stands south of Highway 20 were identified as major emphasis areas for research. For juniper the questions were which sites should be treated, how to treat, and what are wildlife habitat tradeoffs with respect to treatment.

Establishment of forbs for food and of grasses for cover were the main sagegrouse needs identified. The dense sagebrush stand south of Highway 20 is on pumice soil with good moisture characteristics. Additional questions included what are the constraints to restoration and how can they be overcome and what weed control and seeding methods to use in WSAs.

Medusahead and knapweed were identified as noxious weed problems. An increase in cheatgrass has also been identified as a problem. An area along Murderers Creek is being considered for a medusahead burn treatment followed by seeding with squirreltail and/or dropseed *(Sporobolus,* a warm-season grass). *Sporobolus* has made an appearance along the John Day River with a change in season of cattle use from summer-long to winter-early spring use.

Spokane

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A special status plant restoration plan will be implemented in Lincoln County for *Polemonium pectinatum.*

Vale

An estimated 200,000 acres have potentially crossed a threshold into an annual dominated plant community in the Malheur and Jordan Resource Areas. These communities are dominated by mainly cheatgrass and medusahead with halogeton a problem on Salt Desert Shrub areas and knapweeds becoming apparent. The potential for restoration of these sites needs to be determined.

Diversity of extensive crested wheatgrass seedings resulting from the Vale Project could be enhanced by additions of shrub and forb components.

Species needs identified by District staff include: (Grasses) bluebunch wheatgrass, Thurber's needlegrass, Idaho fescue, Indian ricegrass, and basin wildrye; (Shrubs) bitterbrush, curlleaf mountain mahogany and 4-winged saltbush; (Forbs) whatever can be found. Seed sources for virtually all species are lacking. Establishment techniques need to be identified or developed.

A threat or risk analysis to evaluate the need for action against noxious weeds was identified as a need.

Utah

Utah felt that Salt Desert Shrub communities were its greatest concern. The greatest research needs within the Salt Desert Shrub community were oriented toward establishment on low precipitation sites with alkaline soils.

Shrubs for which additional information is desired include shadscale, four-winged saltbush and winterfat. Grasses noted were squirreltail, western wheatgrass and warm season grasses such as Hilaria. For all of these species, information is desired that would aid in predicting ecological success and amplitude. More information is needed in germination characteristics, competition in establishment, and seeding technology.

An inventory is currently being developed for special status plants. Specific research needs will be identified later.

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