Development and Use of Plant Resources for Western Wildlands

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Abstract—Concern for declines in big game habitat throughout the West and the pioneering work of revegetation researchers in the mid twentieth century led to increased use of native shrubs, grasses, and forbs for revegetation, and the 1975 establishment of the U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory in Provo, Utah. During this period revegetation objectives shifted from an emphasis on production of commodities to conservation of biodiversity and ecosystem functions. Plant resource development altered from an agronomic approach focusing on plant improvement to one that incorporates ecological, genetic, and practical considerations. Although many problems remain, research, technological advances, efforts to stabilize the native seed industry, and improved seed testing and certification procedures are increasing our options for revegetating disturbed lands.

At the 1975 dedication of the Shrub Sciences Laboratory, the senior author and Donald R. Christensen, then of the Utah Division of Wildlife Resources, presented a paper “Woody Plants for Rehabilitating Rangelands in the Intermountain Region” (Monsen and Christensen 1976). This paper summarized contemporary and anticipated research needs for the selection and use of native shrubs on disturbed wildlands, particularly big game ranges. Efforts to improve habitat for expanding mule deer populations in the Western States began in the 1940s (McArthur 1992; Plummer and others 1968). Degradation resulting from abusive livestock grazing, agricultural development, and urbanization contributed to loss of shrublands that provided important winter and spring/fall ranges for big game (Plummer 1972; USDA Forest Service 1936). The objective of maintaining healthy deer herds led to plant materials research that emphasized the use of shrubs to provide browse and cover. This effort was led by Federal and university researchers and western Game and Fish Departments working in cooperation with land management agencies (Plummer and others 1957; Roundy 1966).

Concern over deteriorating big game ranges in Utah led to the 1954 initiation of a cooperative program between the Utah Department of Fish and Game and the U.S. Department of Agriculture, Forest Service, Intermountain Research Station (now the Rocky Mountain Research Station) that has endured to the present (Blaisdell 1972; McArthur 1992; Roundy and others 1997). Research resulting from this and similar efforts across the West enabled managers to begin seeding and planting a variety of shrubs as well as native and exotic herbaceous understory species to stabilize disturbances, restore wildlife habitat, and protect watersheds and other rangeland resources (Holmgren and Basile 1959; Hubbard 1962; Hubbard and others 1959; Plummer 1977; Plummer and others 1955, 1968). This research highlighted the importance of recognizing ecotypic variation in native species and matching plant materials to planting site conditions and management objectives. Much of the early work in Utah was summarized in the 1968 publication “Restoring Big Game Ranges in Utah” (Plummer and others 1968). Progress in Utah led to a greater recognition of shrubland resources and values (McKell and others 1972) and the 1975 establishment of the U.S. Department of Agriculture, Forest Service, Shrub Sciences Laboratory in Provo (Blaisdell 1972; McArthur 1992; Stutz 1975).

Plant Material Development and Use, 1912 to 1975

Shrub revegetation research developed from ongoing efforts to stabilize and restore Western wildlands. Livestock grazing excesses in the late nineteenth and early twentieth century negatively impacted vegetation and watershed stability (USDA Forest Service 1936). Massive erosion and major flood events led to the instigation of research and management programs to understand the causes of watershed deterioration and implement grazing management and rehabilitation programs to combat the problem (Forsling and Dayton 1931; Meeuwig 1960). Initial work begun in 1912 centered on disturbances at upper elevations (Monsen and McArthur 1995). In the 1920s a research program was implemented across the Intermountain Region to evaluate the adaptability and performance of a number of grass, forb, and shrub species and accessions (Forsling and Dayton 1931; Monsen and McArthur 1995; Plummer and Stewart 1944). Although native species were included in research studies and field trials from the beginning, exotic grasses were generally more effective in meeting the criteria of ease of planting, reliable establishment, rapid production of ground cover, good palatability and productivity, grazing tolerance, competitiveness with weeds, good seed quality, and low seed cost (Monsen and McArthur 1995). A number of introduced grasses including smooth brome (*Bromus inermis* Ley.), intermediate wheatgrass (*Elytrigia intermedia* [Host] Nevski), and orchardgrass (*Dactylis glomerata* L.) were widely used at mid and upper elevations. Revegetation of degraded sagebrush rangelands in low precipitation areas centered on the use of introduced wheatgrasses (*Agropyron*

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Gaert. spp.). These were seeded on extensive tracts in the Great Basin and northern shrub steppe during the mid 1900s to improve forage availability for livestock and to control the spread of halogeton (*Halogeton glomeratus* [Bieb.] C.A. Mey.) (Johnson 1986; Mathews 1986; Young and Evans 1986).

Thus, for watershed and livestock plantings, a number of exotic grasses gained widespread use, while initial poor showings limited further research with natives (Roundy and Call 1988). In spite of their apparent effectiveness, problems posed by exotic grasses eventually became widely recognized. These included the disruption of soil structure and loss of remnant native species during site preparation for seeding, lack of diversity and vegetative structure in mature stands, and susceptibility to insects, disease, and drought (Box 1986; Pyke 1996). Importantly, exotic grasses often precluded recovery of natives, and in some cases they were subject to invasion by weedy species (Elliot and White 1987; Powell and others 1994; Walker and others 1995). These limitations, advances in shrub research, and a growing public concern for conserving ecological values of rangelands gradually led to increased emphasis on the inclusion of natives and a greater diversity of species in revegetation prescriptions. In addition to improvement of big game range, shrubs and other native species were being recognized as valuable for low maintenance landscaping, recreation areas, roadside disturbances, mined lands, and other severely disturbed sites (Blaisdell 1972; Plummer 1972).

For selection of revegetation plant materials, particularly woody species, researchers emphasized a combination of approaches used in forest tree seed improvement and techniques utilized in developing agronomic plant varieties (Plummer 1972). By this time, the wide genetic variability in terms of ecotypes, biotypes, and chromosome races present in many intermountain species as a result of past climatic change and plant migrations was widely recognized (for example, see Beetle 1960; Stebbins 1950; Stutz and Thomas 1964). Important natural shrub stands were identified for seed collection, and in some cases, seed orchards from selected populations of important species were established (Plummer 1972). Plummer advocated development of geographic ecotypes, selections adapted to specific areas and exhibiting desirable characteristics. These selections might represent particular ecotypes or specific plants from an ecotype, referred to as biotypes or races, that exhibited desirable characteristics (Plummer 1972). These characteristics were generally related to plant establishment or browse production and included germinability, seedling vigor, growth rate, palatability, winter leafiness, and tolerance of browsing (Monsen 1975; Plummer and others 1968).

Many accessions selected for study represented extensive shrub populations that were regularly harvested by commercial collectors and planted throughout the Intermountain area. Seeds from these stands and collections from additional populations of interest were widely field tested for adaptability and performance within and beyond the current range of the individual populations and species (for example, see Davis 1983; Edgerton and others 1983; Shaw and Monsen 1983 for antelope bitterbrush [*Purshia tridentata* {Pursh} DC.] and related species). This research ultimately resulted in the use of a large number of primarily native shrub species and accessions as well as a variety of native and exotic grasses and forbs. At the first major wildland shrub symposium in the Intermountain area, held in Logan, Utah, in 1971, Blaisdell (1972) reported that extensive screening and testing of shrubs by the Intermountain Research Station, the Utah Division of Wildlife Resources, and the Idaho Department of Fish and Game had resulted in the listing of approximately 75 woody species as promising for restoration of big game habitats (Plummer and others 1968). Of this group, about a dozen were most widely planted in large restoration projects. Four shrubs were considered the primary species to be investigated and promoted. These were basin big sagebrush (*Artemisia tridentata* [Nutt.] ssp. *tridentata*), fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.), antelope bitterbrush, and rubber rabbitbrush (*Chrysothamnus nauseosus* [Pallas] Britt).

Revegetation research fueled further studies of shrubland ecology and management (for example, see Giunta and others 1978; Nord 1965; Stevens and others 1977**)** and contributed to the expansion of the native seed industry. Observed variability in intermountain species led to studies of the genetic and physiological basis for these differences and contributed to our understanding of the evolution of the intermountain flora (Blauer and others 1975, 1976; Drobnick and Plummer 1966; McArthur, this proceedings; McArthur and others 1979; Stutz and others 1975; Stutz and Thomas 1964). Several seed companies began business in central Utah and near other centers of revegetation research and application within the region. Most companies handled both exotic and native species. Steep slopes and unstable sites where rapid establishment was critical were often transplanted rather than seeded, providing researchers and Federal, State, and private nurseries the impetus to develop propagation technology for requested species (Ferguson and Monsen 1974; Heit 1967, 1968, 1971; Schopmeyer 1974).

Early recognition of the cycle of excessive grazing, creation of openings in plant communities, invasion by annual weeds, changes in fire frequency and behavior, and alteration of secondary succession guided research on the establishment of wildland plantings (Plummer 1972). Germination, seedling establishment, and growth data from field trials were used to develop appropriate planting technologies and prescribe management and use of young plantings (Basile and Holmgren 1955, 1957; Plummer and others 1968). Existing agricultural equipment was adapted for harvesting, cleaning, and seeding the highly varied types of fruits and seeds planted. The Equipment Development Committee, comprised primarily of agency and commercial members, was established in 1942 to address the development of a disk and drill seeder for rangeland conditions (Larson 1982). Development of the Hansen seed dribbler, interseeders, aerial seeding devices, the anchor chain, and the rangeland drill enabled land managers to plant mixtures of potentially competitive species on rugged terrain (Larson 1982; Vallentine 1989).

Plant Materials Use and Development, 1975 to 2000

Federal Land Revegetation Policy

Changes in Federal land management policy during the twentieth century reflected trends in public concern for the condition and sustainability of public land resources and have directly or indirectly dictated approaches to the selection and use of plant materials. Over this period, policy shifted from an emphasis on commodity production to facilitation of multiple uses to conservation of biodiversity and ecosystem management (Davis 1997; Loomis 1993; Richards and others 1998; Tzoumis 1998). Current guidance for revegetation of Federal lands has evolved over the last 40 years and generally encourages the use of native species when feasible or practical (table 1). Additional direction is available for specific agencies and categories of land disturbances (see below). Land managers planning revegetation efforts are now attempting to address the scale-associated problems of reestablishing vegetation not only on site-specific projects but within the context of management at the landscape level (Bell and others 1997; Ehrenfeld and Toth 1997; Jelinski 1997; Whisenant 1999). Local revegetation policies and guidelines evolve and are updated more or less continuously (for example, USDA Forest Service 2000a; USDI Bureau of Land Management 1996). Concerns and conflicts revolve around genetic considerations, social acceptance of site preparation practices such as herbicide use or chaining, the use of exotics to control weeds or to reduce the spread of wildfires, protection of threatened and endangered plant and animal species, and preservation of local gene pools.

Drastically Disturbed Lands

Early efforts to reclaim mine disturbances on public lands emphasized the use of exotic grasses and forbs to provide rapid site stabilization and forage for livestock and wildlife. Sharply increasing public awareness and concern for environmental issues in the 1960s and the greater private funding available to meet compliance for bond release for revegetation of mined lands effected a gradual shift to the inclusion of greater numbers of native species in seeding mixes (Redente and Keammerer 1999). The Surface Environment and Mining Program (SEAM), chartered by the Forest Service in 1973, sponsored technology

Table 1—Selected Federal legislation and Executive Orders and Memoranda impacting the selection and use of plant materials, 1960 to present.

Document	Year	Direction
Multiple Use Sustained Yield Act (P.L. 86-517; U.S.C. 528-531)[a]	1960	Agencies directed to manage reserved Federal lands for recreation, watershed values, grazing, timber, fish, and wildlife, thus increasing the emphasis on noncommercial resources.
Classification and Multiple Use Act (P.L. 88-607; 43 U.S.C. 1411-1418)[a]	1964	Agencies directed to manage reserved Federal lands for recreation, watershed values, grazing, timber, fish, and wildlife, thus increasing the emphasis on noncommercial resources.
Wilderness Act (P.L. 88-577; 16 U.S.C. 1131-1136)[a]	1964	Provided for designation of wilderness areas to be “preserved and protected in their natural condition.”
National Environmental Policy Act (P.L. 91-190; 42 U.S.C. 4321 et. seq)[a]	1969	Federal agencies directed to analyze impacts of proposed disturbances in environmental assessments and include public participation in decisionmaking.
Forest and Rangeland Renewable Resources Planning Act (P.L. 93-378; 16 U.S.C. 1610-1616)[a]	1974	Federal agencies required to assess use and availability of natural resources on Federal lands and develop management direction for National Forests.
National Forest Management Act (P.L. 94-588; 16 U.S.C. 1600-1616)[a]	1976	Directed National Forests to submit management plans every 5 years.
Federal Land Policy and Management Act (P.L. 94-579; 43 U.S.C. 1701 et. seq.)[a]	1976	Prescribed BLM response to the Resources Planning Act. Required planning to protect biodiversity, designate wilderness study areas, and control extraction of locatable minerals.
Endangered Species Act (P.L. 93-205; U.S.C. 1531-43)[a]	1973	Responsibility for managing endangered species and their habitat transferred from the States to the U.S. Department of the Interior, Fish and Wildlife Service.
Executive Order 11987—Exotic Organisms (Carter 1977a)	1977	Federal agencies directed to restrict the introduction of exotic species into natural ecosystems.
Executive Memorandum on Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds (Clinton 1994)	1994	Prescribed use of regionally native plants for landscaping Federal grounds, Federal projects, and Federally funded projects using low input landscaping practices.
Executive Order 13112—Invasive Species (Clinton 1999)	1999	Directed agencies to provide for restoration of native species and habitat conditions in ecosystems invaded by exotic species.

[a]For text see: Cornell Law School, Legal Information Institute (2000).

transfer programs and encouraged research that contributed substantially to plant material development, revegetation technology, and further growth of the native seed and plant industry (for example, see USDA Forest Service SEAM n.d.; USDA Forest Service 1979). The Surface Mining Control and Reclamation Act of 1977 (SMCRA; P.L. 95-87; 30 U.S.C. 1201 et seq.) (Cornell Law School, Legal Information Institute 2000) reinforced these efforts, mandating "a diverse, effective, and permanent vegetative cover of species native to the disturbed land or species that will support the planned post-mining uses of the land."

The SEAM Program and the SMCRA contributed to major advances in technology and plant materials development for revegetation of other disturbed lands. Plant materials selected primarily for mined land revegetation by universities and USDA NRCS Plant Materials Centers, Agricultural Research Service and Forest Service received widespread use. Development of seed and seeding technology, revegetation equipment, and plant propagation protocols facilitated use of an increased number of species. Research related to plant succession, weed invasions, and competitive interactions in mixed plantings on mined sites increased knowledge of native flora and led to overall advances in wildland revegetation.

DePuit and Redente (1988) examined long-term results obtained from seedings of native and introduced species on mined lands. They determined that introduced species might be more appropriate for rapid control of erosion. However, they found a stronger relationship between mature community structure and composition of the seed mix when native rather than exotic species were seeded. Although cost and establishment of native species were problematic, they concluded that reestablishment of native communities offered a number of advantages compared to exotic seedings. These included greater sustainability, lower management inputs, ease of integrating management of reestablished communities and surrounding native communities, and better quality of wildlife habitat produced.

Big Game Ranges

A wide assembly of ecotypes of shrub species considered important for big game ranges in Utah were collected for field trials prior to 1970. These plantings, coupled with seed germination and establishment studies, provided data required to support the release of a number of widely adapted woody and herbaceous cultivars by the USDA Forest Service, Utah Division of Wildlife Resources, and cooperators (McArthur, this proceedings). Some of these cultivars and an increasing number of other species were brought into cultivation for production of seeds for restoring big game ranges while seeds of others continued to be collected from wildland stands.

Establishment and maintenance of a seed warehouse by the Utah Division of Wildlife Resources aided in improving the availability of native and exotic species and ecotypes (table 2). This agency established procedures for purchasing a constant supply of seed each year, stabilizing the market and assuring sufficient sales to promote collection and marketing a number of species. It defined seed quality standards, delineated geographical regions or collection zones, and developed procedures to clean seeds of many native species. Other agencies and users benefited from this effort, as more species became increasingly available to a growing number of buyers. As seeds of additional species, particularly shrubs, began to be marketed regularly, it became possible to revegetate more shrub-dominated communities.

Table 2—Number of native and introduced species seeded by the Utah Division of Wildlife Resources during selected years from 1959 to 1999[a].

Origin	Life form	1959	1969	1979	1989	1999
Native						
	Grasses	0	4	6	9	19
	Forbs	0	6	8	8	9
	Shrubs	8	16	22	20	12
Introduced						
	Grasses	9	9	11	15	11
	Forbs	3	4	7	14	8
	Shrubs	1	0	1	1	1

[a]Walker 2000.

A number of seed companies specializing in the sale of native plants were established by the mid 1970s and provided a more constant supply of seed, particularly species required for game habitat improvement. The Utah Division of Wildlife Resources continued to support seed production studies for species grown under cultivation. Commercial growers who used information obtained from these studies were able to rapidly expand seed production.

Two rather important changes in revegetation priorities altered the emphasis on species selection for plantings. Prior to about 1980, considerable emphasis was given to planting key winter browse species such as antelope bitterbrush, fourwing saltbush, Stansbury cliffrose (*Cowania mexicana* D. Don var. *stansburiana* [Torr.] Welsh), and mountain mahoganies (*Cercocarpus* H. B. K. spp.) (Giunta and others 1978; Stevens and others 1977; Tiedemann and Johnson 1983; Tiedemann and others 1984). These and other species were commonly planted on sites where they did not naturally occur. Attempts to establish and maintain the shrubs in "offsite" growing conditions, particularly degraded sagebrush rangelands, were eventually recognized as being ecologically unsound. Seeding mixes were reevaluated to include species that were site adapted regardless of their forage traits. In addition, sagebrush and rabbitbrush, once the focus of agency weed eradication programs, gradually gained acceptance as appropriate revegetation species. This contributed to a major shift in seed demands (Rosentreter and Jorgensen 1986). Species of sagebrush and rabbitbrush are now among the most widely seeded.

Recent declines in stands of some native species and populations have impacted revegetation priorities. Cheatgrass expansion and increased wildfire frequency have resulted in the loss of extensive stands of antelope bitterbrush, Stansbury cliffrose, mountain mahogany, and Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle and Young). In many cases the loss of these stands has severely limited the use of ecotypes that once dominated large areas.

Wetlands and Riparian Areas

Improvement of degraded riparian systems became a major management concern in the Western United States in the late 1970s and early 1980s (Swanson 1988). Damage to streams and associated riparian areas resulting from livestock grazing practices and other human activities impaired watershed function, decreased biological diversity, and adversely impacted economic and recreational activities both locally and downstream. Growing public recognition of the magnitude of these problems led to efforts to improve stream functioning and riparian condition through improved management or, when necessary, through active restoration (Kauffman and Krueger 1984; Skovlin 1984; Thomas and others 1979).

Concern over the condition of wetland and riparian areas also led to formulation of Federal policy to preserve and restore these habitats. Direction was provided by such documents as the Clean Water Act of 1972 (P.L. 92-500; 33 U.S.C. 1251 et seq.) (Cornell Law School, Legal Information Institute 2000) and amendments directing pollution control of streams, lakes, and estuaries; Executive Order 11988—Floodplain Management (Carter 1977b); and Executive Order 11990—Protection of Wetlands (Carter 1977c). Additional legislation and programs including the "Swampbuster" Provisions of the Food Security Act of 1985 (P.L. 99-198; 7 U.S.C. 1281 et seq.) and the Conservation Reserve Program authorized by this Act, the North American Wetlands Conservation Act of 1989 (P.L. 101-233; 16 U.S.C. 4401 et seq.), and the Wetlands Reserve Program authorized by the Food, Agriculture, and Conservation and Trade Act of 1990 (P.L. 101-624; 16 U.S.C. 3801 et seq.) support restoration and management of degraded wetlands, primarily on private lands (Cornell Law School, Legal Information Institute 2000; Mitsch and Gosselink 1993; Tzoumis 1998; White and others 1992). Both the Conservation Reserve Program and the Wetlands Reserve Program are administered by the USDA NRCS.

Restoration of disturbed wetland and riparian areas requires that affecting factors first be identified and controlled at the watershed level to restore proper hydrologic and biologic functioning. In many cases, adjustments in management permit natural recovery of riparian vegetation in these systems (Goodwin and others 1997; Hawkins and others 1997; Landers 1997). Seeds or vegetative material may be planted when active restoration is dictated by loss of seed or plant sources, drastic declines in the water table, or other factors. Wetland and riparian plantings have centered on the use of native species, and where possible, local populations (Borman 1996; Carlson 1992; Hughes 1996; Lambert 1995; Willard and Reed 1986). Vegetation in wetland and riparian areas exhibits high species diversity. Thus, revegetation of these areas has generated a demand for seed and planting stock of numerous species receiving little use in the past, but which are now often included on the availability lists of many nurseries and seed dealers.

Many wetland species are distributed across wide geographic and elevational ranges. Local accessions are generally selected for planting as little is known about genetic variation or the range of adaptation of individual populations within these species. Numerous riparian species spread vegetatively; plugs, wildings, rhizome sections and cuttings of these species are easily propagated and planted. Container seedlings, larger plants, cuttings, or poles are used on unstable sites prone to flooding and in areas where the water table declines substantially in summer. Results of recent research on seed germination requirements, the relative ease of storing and handling seeds, and concern for disturbances created by collection of vegetative material are contributing to increased use of seed for propagating riparian species.

The USDA NRCS Plant Materials Program has played a key leadership role in the selection and use of plant materials for riparian and wetland areas. Research conducted by Plant Material Centers provides much of the available data on variability within wetland and riparian species (Flessner and others 1992) as well as guidelines for their propagation and planting (Hoag 1995). Guides developed by the USDA NRCS aid in selection of native species that can be used successfully for revegetation within Major Land Resource Areas (Lambert 1999) or larger geographic areas (Bentrup and Hoag 1998; Lambert 1995; Ogle and others 2000). In addition, the agency has released a series of source-identified wetland and riparian plant materials for use when local sources of seed or vegetative material are not available (Englert and others 1999).

Wildfires and Weed Invasions

Throughout the twentieth century, the invasion of cheatgrass (*Bromus tectorum* L.) and other annual weeds onto rangelands degraded by excessive livestock grazing and other disturbances contributed to lengthened fire seasons and increased fire frequencies (Whisenant 1990; Young and others 1987). The annual grass/fire cycle enhances the spread of annual and perennial weeds, destroys native communities, and reduces ecosystem resilience (Entwistle and others 2000; McArthur and others 1990; Monsen and Kitchen 1994). By 1992 about 1.3 million ha of USDI BLM lands were dominated by annual grasses, and 30.8 million ha of public rangelands were weed infested or susceptible to invasion (Pellant and Hall 1994). From 1991 to 2000 an average of 645,113 ha of USDI BLM lands burned each year (USDI BLM 2000a). Post-fire rehabilitation efforts to reduce the spread of weeds, fuel buildup, and ecosystem simplification are conducted on a landscape scale and have provided a major impetus to growth of the wildland seed industry (table 3). The USDI BLM Emergency Fire Rehabilitation Handbook provides guidance for these projects and prescribes the use of native materials when available (USDI BLM 1998). Executive Order 13112—Invasive Species prescribes use of native materials to restore areas invaded by weeds (Clinton 1999). Introduced species received extensive use in the past due to their availability, low price, and ability to establish in low precipitation areas with high potential for weed invasion. Recent developments in site preparation techniques at the research and application levels offer promise of aiding the establishment of native species (Meyer and others 2000; Pellant and others 1999; Shaw and Monsen 2000). The increasing availability and use of native grass seed cultivars, particularly of native wheatgrasses including thickspike wheatgrass (*Elymus lanceolatus* Scribn. & J. G. Smith), Snake River wheatgrass (*Elymus wawaiensis* J. Carlson), and western wheatgrass (*Pascopyrum smithii* [Rydb.]) as

Table 3—Seeds purchased by the USDI Bureau of Land Management, Denver Federal Center, in three 2001 buys[a].

Origin	Life form	Certified site-identified or certified variety			BLM specified origin or noncertified variety		Origin not specified or noncertified, variety not specified	
		Species	Varieties	Pounds	Species	Pounds	Species	Pounds
Native								
	Grasses	16	23	1,448,300	13	246,600	6	52,950
	Forbs	0	0	0	2	2,100	4	28,650
	Shrubs	5	3	180,710	9	559,060	6	32,945
	Total	21	26	1,629,010	24	807,760	16	114,545
Introduced								
	Grasses	11	15	664,100	7	527,300	1	1,000
	Forbs	6	6	290,350	4	133,900	3	24,400
	Shrubs	1	1	5,300	1	157,800	0	0
	Total	18	22	959,750	12	819,000	4	25,400

[a]USDI Bureau of Land Management (2001).

well as wildland harvested Wyoming big sagebrush caused the balance of USDI BLM purchased seed to shift to regionally native species (Pellant and Monsen 1993) (table 3). However, the need to further diversify seedings in terms of species and populations and associated challenges are recognized.

Although many problems remain, efforts to restore native communities on rangelands over the last 2 decades have led to major advances in development of equipment for site preparation and seeding of mixtures and trashy seeds at appropriate rates and depths. Innovative methods are being implemented to insure seed availability and origin. Seed warehousing by the USDI Bureau of Land Management in Boise, Idaho, has added a measure of stability to the seed industry, improved the availability of seed supplies, and provided cold storage facilities for short-lived seeds.

National Forests have traditionally seeded introduced annual and perennial grass and forb cultivars and available native grass cultivars to provide soil stabilization following forest fires. However, concerns exist that the seeded grasses fail to provide adequate protection during the first season post-fire, and that the introductions may be highly persistent, sometimes invasive, and preclude recovery of native vegetation (Clark and McLean 1979; Powell and others 1994; Robichaud and others 2000). A recent update of the USDA Forest Service Burned Area Emergency Rehabilitation Handbook prescribes use of genetically local sources of native plants when possible or nonpersistent, noninvasive species if local material is not available (USDA Forest Service 2000d). Some National Forests are promoting the collection of local seed sources and seed increase of selected grasses and forbs. Seed transfer guidelines for the most commonly used shrubs are being developed for the Intermountain area (Mahalovich 2001a,b).

The magnitude of the wildfire and weed issues has contributed to the establishment of government programs and initiatives for plant materials development and use. The USDI BLM Green Stripping Program (Pellant 1990) was established in 1984 to develop technology for establishing fuel barriers to protect existing shrublands and plant materials for restoring native communities. Executive Order 13112—Invasive Species prescribed restoration of native species and habitats, where possible, on areas invaded by alien species (Clinton 1999). The extreme fire seasons of the last decade (1991 to 2000) contributed to development of the Great Basin Initiative, a proposal that provides a blueprint for planning and implementing a restoration program for Great Basin Ecosystems (USDI BLM 2000b).

Other Land Disturbances

Native and introduced plant materials are used for revegetating or mitigating an array of disturbances on public and private lands. The USDA NRCS and USDI National Park Service have collaborated since 1989 on a program to develop plant materials for revegetating roadway disturbances in National Parks (Haas 2001; Link 1993). To date, plant materials of more than 800 accessions of native species have been tested and increased, and 9,000 kg of seed and 520,000 seedlings have been produced through this agreement (Haas 2001). The U.S. Department of Transportation, Federal Highway Administration, provides policy guidance for revegetation conducted by State Departments of Transportation. Several Western States have native wildflower programs; current challenges are to combat invasive weeds and reestablish native species and communities where practical (Harper-Lore 1999, 2001). The Federal Native Plant Conservation Memorandum of Understanding, originally signed by 10 Federal agencies in 1994, established a committee to identify conservation needs for native plants, including the restoration of native species on public lands and promotion of similar activities on private lands. To date, 174 public and private organizations have signed on as cooperators with the committee (Plant Conservation Alliance 2001). This organization has the lead within Department of the Interior agencies to increase the availability of native plants (Office of Management and Budget 2001).

The Conservation Reserve Program (CRP), managed by the USDA NRCS, compensates landowners for retiring highly erodible land for 10 years (USDA Farm Service Agency 2001a). Providing the seed required for plantings on these lands has created a challenge for the conservation and wildland seed industry. From 1987 to 2001 nearly 4.4 million ha of CRP lands in the 11 Western States were planted with introduced grasses to improve soil stability, while another 6.9 million ha were planted with regionally native grasses (USDA Farm Service Agency 2001b). Plantings to improve wildlife habitat were installed on about 250,000 ha. During many years, insufficient seed of requested species, cultivars, or specific populations has been available for both CRP plantings and post-fire seedings on public lands. The result is that prices escalate and alternatives to the desired species mix are often purchased and seeded.

Genetic Considerations in Selecting and Using Plant Materials

Research during the past quarter century has considerably increased our knowledge of genetic diversity in western wildland species (for example, see McArthur, this proceedings). However, much remains to be learned regarding variability within individual species. Seed collectors, seed growers, nurserymen, agency personnel, revegetation practitioners, and researchers recognize that genetic considerations must play a role in selecting planting materials for revegetating disturbances. Controversy has arisen over the use of native versus exotic species, definitions of "native," and specifications for selection of native plant materials in order to preserve local populations (Belnap 1995; Gutknecht 1992; Millar and Libby 1989; Pyke 1996; Rice 1996). At issue is the question of whether gene flow between the seeded and local populations of cross-pollinated species will impede natural selection in the local populations and "swamp" or "pollute" their gene pool, or whether local populations might be outcompeted if nonlocal sources are planted, regardless of the plant's breeding system (Jones 1997b; Linhart 1995; Millar and Libby 1989; Rice 1996). At the same time, introgression can be an important evolutionary force, creating new gene complexes and potentially greater adaptability (Jones and Johnson 1998).

Researchers have attempted to provide frameworks for making appropriate plant material selections. Monsen and McArthur (1995), for example, proposed classifying sites into two categories:

> Type 1—Sites that are badly degraded or otherwise changed by loss or change of topsoil or by radical change of topography, hydrology, or fire cycles, or that have a high priority use such as watershed protection. These sites should be treated with the most appropriate plant materials available, indigenous or non-indigenous, for meeting critical objectives such as site stabilization, weed control, or protection of watershed values.
> Type 2—Sites with good potential for restoration to natural conditions. These sites should be treated and managed to return them to near predisturbance conditions.

Jones and Johnson (1998) recommend first assessing the site potential and desired landscape for the disturbance, determining seeding objectives, and considering the genetic integrity of materials to be used. The latter includes selection of material genetically similar to that occurring on the site and insuring that genetic shifts are minimized throughout the propagation cycle. Practical considerations or feasibility factors then enter into the process. These include seral status of the disturbance, examination of the presence or potential for weed invasions, and economic constraints. Within this framework the species list is reassessed and finalized. Appropriate genetic material for each species must then be selected. Scale of the disturbance, time and economic limitations, and seeding objectives often dictate the degree to which specific gene pools can be selected. Local seed sources are much more likely to be available for small-scale plantings than for portions of the sagebrush steppe heavily impacted by large fires.

Selection of appropriate plant materials is hindered by our limited knowledge of the reproductive biology and genetics of individual wildland species. For introduced species, selection generally involves identification of the cultivar most suited to the planting site. For natives, the problem is more complex. Ecotypes, biotypes, and chromosome races occur within many species and may be selected for specific site conditions (Borman 1996; Jones 1997b; Jones and Johnson 1998). For more extensive disturbances, collections of a single taxa gathered from sites throughout the area may be combined to form multiple component plant materials. These provide broad genetic diversity and adaptation to the range of conditions encountered within the disturbance (Jones 1997b; Millar and Libby 1989; Munda and Smith 1995; Stutz 1983). Materials released through the variety or pre-varietal release program may be options when local seed sources are unavailable. Plant breeding techniques may be utilized to overcome specific problems such as seed dormancy that prevent the use of a species for revegetation (Jones 1997b). Plant breeding approaches such as the use of multiple component materials and modified convergent-divergent selection processes are used to breed plant materials with increased rather than narrowed genetic diversity for potential use on extensive disturbances (Munda and Smith 1995).

Seed Certification

Early revegetation plantings generally utilized seed harvested from noncertified stands of introduced or native grasses or from wildland stands of natives. Selection trials for improved plant materials suitable for revegetation work, generally grasses, were conducted using agricultural plant selection and breeding methods and materials were released to commercial growers as cultivars through State Crop Improvement Associations. The International Crop Improvement Association, organized in 1919 with members in the United States and Canada and renamed the Association of Official Seed Certifying Agencies in 1968, fostered development of improved crop varieties, uniform naming of cultivars, and a certification system for regulating the propagation, multiplication, and dissemination of improved seed (Copeland and McDonald 1985). The four generation system adopted led to production of "blue tag" or certified seed, which provides growers with assurance of genetic purity and acceptable quality. Field isolation requirements, checks for weeds and off-types, and inspection of seed conditioning, quality, and identity are some of the services provided through the certification system (Copeland and McDonald 1985). Limitations on numbers and lengths of generations that cross-pollinated varieties may be grown outside the area of use are applied when necessary to reduce the risk of genetic drift.

Some of the earliest cultivars used on wildlands were released in the 1940s. Examples include the introductions

'Manchar' smooth brome released in 1943 and 'Greenar' intermediate wheatgrass released in 1946 (Englert and others 1999), and the natives 'Bromar' mountain brome (*Bromus carinatus* H. & A.) and 'Primar' slender wheatgrass (*Elymus trachycaulus* [Link] Gould ex Shinners) released in 1946. The USDA Natural Resources Conservation Service, Agricultural Research Service, and Forest Service; land grant universities; and other public and private entities continue important programs to test individual species for range of adaptation and specific desirable traits and to develop widely adapted releases for wildland seedings (Alderson and Sharp 1994; Englert and others 1999; McArthur, this proceedings). Physiological tests including measurements of respiration and temperature have been developed in an attempt to provide a more rapid assessment of adaptability than the normal series of field trials (Jones and others 1999; McArthur and others 1998; Monaco and others 1996; Smith and others 1996).

The formal release system generally functions well for introduced grasses and legumes and for some native species that can be reliably produced in seed fields or seed orchards. However, the highly ecotypic nature of many wildland species, low seed production, and problems encountered in producing some species under agricultural conditions due to difficulties encountered in harvesting, conditioning, planting, and stand establishment hindered cultivar development for other important native species. Erratic or limited market conditions and storage problems associated with some species further frustrated these efforts. Most woody species require several years of growth before producing seed, thus slowing testing and establishment of shrub seed orchards and reducing the opportunity for economically viable production. In light of these and other problems and the numerous species, ecotypes, and local populations potentially required for revegetation efforts, seed collectors and growers have employed a variety of methods in addition to the formal release process for providing plant materials for revegetation. Grass and forb seeds are collected from wildland stands where they can be mechanically harvested or easily hand harvested. Shrub seeds are collected from major wildland stands or from areas producing good seed crops in a given year. Some easily grown, nonselected populations are planted in seed fields or orchards and harvested. Agencies and other entities purchasing seeds have adapted approaches for obtaining seeds from desired species and locations. The Utah Division of Wildlife Resources purchases and warehouses seeds from specified areas to meet anticipated needs. The USDI Bureau of Land Management may specify specific stands for collection with agency overview (Fritz 2001). In British Columbia, the Ministry of Forests has published a general transfer guideline for nontree species and recommended that the use of the same seed planning zones developed for trees be applied to these species (Bakker 1999).

Buyers, however, have continually faced difficulties in obtaining adequate quantities of seeds of known origin to insure that the seed source will be adapted to planting conditions. In an attempt to deal with this problem, The Association of Official Seed Certification Agencies has developed a Source Identified seed program for revegetation species by modifying the long-established Source Identified program utilized for tree seed (Currans and others 1997; Young 1995, 1996; Young and others 1995). This program applies to both wildland-collected and field-grown seed or vegetative material of indigenous or nonindigenous species. Verification of identity for field-grown seed is conducted as for the traditional release system. Due to limitations of personnel and funding, however, onsite inspections of wildland collections often occur for only a fraction of the applications (Currans and others 1997).

The alternative "Source-Identified" or "Pre-variety Germplasm Certification" Program is considered a "fast track" approach for making available genetically manipulated or nongenetically manipulated (natural track) plant materials of known origin when there is an immediate need for the material, alternative sources are not available, or market limitations preclude the development of the germplasm to the cultivar status (AOSCA 1997). Germplasms are designated "Source-Identified" when the geographic origin is known, but no comparisons have been made with other germplasms of the species. "Selected Class" germplasm demonstrates promise of superior or unique traits when grown in common gardens with other germplasms of the same species, while "Tested" germplasm maintains these traits through progeny testing. "Tested" germplasms may be released as named cultivars if they are found to be widely adapted and market conditions warrant the release (Young 1995, 1996; Young and others 1995). Most material released through this program falls into the nongenetically manipulated "Natural" category. Within each category, plant materials are further identified by the number of generations they are removed from their origin. As with the traditional certification program, the number of generations permitted for seed production and the restrictions on the number of years seed may be collected from a perennial seed field or orchard vary among species (AOSCA 1997). Although not adopted until 1993, the Pre-variety Germplasm Certification program is seeing widespread use. More than 50 percent of USDA NRCS releases during the 1990s were released through this program (table 4). In Utah, 95,262 kg of wildland collected seed were Source-Identified in 1999 (Young 2001). About 23 percent of USDI Bureau of Land Management native shrub seed purchases based on weight of pure live seed were Source-Identified in 2000 (table 3) (USDI BLM 2000c).

Seed Quality

The last 25 years have seen major advances in the development of procedures for testing the seed quality of native and introduced species used for revegetation. Difficulties are encountered due to the large number of species, subspecies, and varieties being used and the extreme variability in morphology, dormancy, and germination requirements encountered among taxa, populations, and years of collection. Reliable measurements of seed quality are critical for setting and comparing seed prices and for calculating seeding rates. Numerous studies of the seed ecology and biology of revegetation species have been conducted over the last quarter century (see references in McArthur, this proceedings, for contributions of the Shrubland Biology and Restoration Project and cooperators alone). However, resources expended for the study of even common species are extremely limited compared to research funding for individual

Table 4—U.S. Department of Agriculture, Natural Resources Conservation Service plant releases by decade, 1950 to 1999[a].

		1950–1959		1960–1969		1970–1979		1980–1989		1990–1999	
Origin	Life form	Pre-varietal releases	Cultivars	Pre-varietal releases	Cultivars	Pre-varietal releases	Cultivars	Pre-varietal releases	Cultivars	Pre-varietal releases	Cultivars
Native											
	Grass	0	5	3	11	0	24	0	27	39	24
	Forbs	1	0	2	0	0	7	0	9	21	4
	Shrubs	0	0	0	1	0	9	0	24	8	13
	Trees	0	0	0	0	0	1	0	9	6	7
Introduced											
	Grasses	10	15	1	13	1	13	0	15	2	10
	Forbs	4	3	4	7	1	6	0	10	0	7
	Shrubs	0	0	0	1	0	8	0	4	0	1
	Trees	0	0	0	0	0	4	0	2	1	6

[a]Englert and others 1999.

agricultural crop species. The seed biology of many native genera and species remains essentially unknown.

Seed laws in most States require that a licensed laboratory test the seed lots before or at the time of sale (Currans and others 1997). Problems have occurred throughout the history of revegetation efforts in the Western United States because tests were not always completed and seed of very low quality was sometimes sold. Some laboratories do not accept seed lots of species for which there are no rules. Others accept seed lots and apply tests developed in-house with procedures and results varying from laboratory to laboratory. The Association of Official Seed Analysts (AOSA) and other organizations have attempted to address problems associated with testing native seeds. A user's guide to the procedures, values, and interpretation of seed tests and results was developed by the Western Forest and Range Seed Council in 1986 (Stein and others 1986). In 1998 the AOSA organized a symposium that addressed problems and progress in native seed testing (AOSA 2001).

Tests most commonly conducted include purity, seed weight, and germination or viability. Problems encountered in purity testing result largely from inadequate or nonrandom sampling. For some species, further problems are introduced by differences in interpretation of the seed unit (Kitchen 2000). Purity testing is particularly problematic for species such as winterfat (*Ceratoides lanata* [Pursh] J. T. Howell) or prostrate kochia (*Kochia prostrata* [L.] Schrader) that typically produce many small or empty fruits and for sagebrush, rabbitbrush, and other species that are often sold at low purities. In addition, purity tests for such seed lots can be extremely time consuming and costly. Recommendations for sampling and quantities of seed required for testing, refined definitions of the seed unit for problematic species, and training sessions for users as well as seed analysts are included among approaches for improving estimates of purity and their interpretation (AOSA 2000; Currans and others 1997; Stein and others 1986).

Although the average numbers of seeds per kilogram have been published for many species (AOSA 2000; Redente and others 1982; Schopmeyer 1974; Stevens and others 1996; Vories 1980), these can differ immensely among populations and collection years. The number of seeds per kilogram is also dependent upon the extent to which various structures surrounding the fruit or seed are removed during cleaning (Kitchen 2000). Thus, in many cases tests of individual seed lots are necessary for completing seeding rate calculations.

Assessments of seed germinability and viability are critical to determination of seed quality. New AOSA rules for testing germination of additional wildland species are being developed, refereed, and adopted each year (AOSA 2000). Cooperative agreements (1985 to 1989 and 1997 to present) between the Utah Department of Agriculture (now Utah Department of Agriculture and Food), the Utah Division of Wildlife Resources, and the Shrub Sciences Laboratory have contributed to the adoption of 37 rules for widely used revegetation species (Kitchen 2000; McArthur, this proceedings). Difficulties arise when species without rules must be used. Currans and others (1997) reported that 67 percent of the species sold by two Utah seed companies, including many commonly sold species with named cultivars, did not have rules. Additional problems arise as native and exotic revegetation species often exhibit extreme dormancy, and variability in dormancy and germination requirements often occur among and within seedlots of individual taxa. Development of additional rules and innovative approaches for testing germination of species exhibiting variability in germination requirements within or among populations are needed to reduce these problems (Kitchen 2001).

Viability testing using tetrazolium chloride staining is often used as an alternative to germination testing when a rule is not available or when lengthy time periods are required for germination (Peters 2000). A revised handbook on tetrazolium testing prepared through collaboration by the AOSA and the Society of Commercial Seed Technologists (Peters 2000) updates the original handbook that emphasized agricultural species, primarily grasses (Grabe 1970). The new volume provides procedures for 103 families and 375 genera. Difficulties continue due to differences in interpretations of embryo staining, inadequate analyst experience and training, and a need for additional guidelines. Limitations result from the inability of viability tests to detect dormancy, minor seed damage, disease, fungal infections, or chemical or fungicide damage (Vankus 1997). Additional research on viability testing and opportunities for analysts to work with individual wildland species are needed to further improve the value of viability tests (Currans and others 1997).

Site Preparation and Planting

Development of effective site preparation and planting practices and equipment have been major goals of revegetation research in the Intermountain area from the beginning (Holmgren 1956; Jordan n.d.; Plummer and others 1957). Reducing competition on rangelands infested with annual grasses and rapidly spreading perennial weeds (Sheley and Petroff 1999) and planting mixtures of species with diverse seeds across extensive and irregular terrain present complex problems. As a greater array of native species are now being planted together to reestablish more complete communities, seedbed preparation and planting methodologies must become more complex. Seeds of individual species require specific seeedbed conditions and emerging seedlings differ widely in resource requirements and growth rates. Seeds of different species often must be planted at different depths and seeded at different rates to attain desired densities. Through the efforts of the Revegetation Technology and Equipment Committee (originally the Equipment Development Committee, later renamed the Vegetative Rehabilitation and Equipment Workshop), commercial enterprises, agency personnel, and others, major advances in revegetation equipment development have occurred over the last two decades. However, modification of agricultural equipment and the design and fabrication of equipment for the relatively small rangeland market continue to pose a challenge for commercial enterprises.

Disturbed rangelands generally support competitive weeds that must be controlled if new plantings are to survive and establish. Mechanical tillage, burning, and herbicides treatments are frequently employed to reduce competition. A major challenge has recently arisen in the restoration of rangelands where retention of residual species is desired. Remnant native broadleaf herbs, grasses, and shrubs often persist in low numbers in degraded communities. These plants may provide critical seed sources ultimately needed to repopulate the site. Selective treatment to reduce competition and establish desired species is accomplished by interseeding strips or patches within the area to initiate or hasten natural recovery. Improved approaches for interseeding would find widespread application.

Literature and Databases

Numerous efforts have been made over the last 25 years to summarize research data on the use of native and introduced species for revegetation and to make it more readily available to users. The U.S. Department of Agriculture, Agriculture Handbook 450, Seeds of Woody Plants in the United States, originally published in 1948 and expanded in 1974 (Schopmeyer 1974), summarized data of use to nurserymen and seed dealers for propagation of trees and woody shrubs. The book was again revised by Young and Young (1992), and is currently undergoing a major revision and expansion by the USDA Forest Service (USDA Forest Service 2000e). Numerous other publications summarize information on germination of wildland grasses, forbs, shrubs and trees. Some also include ecological information, propagation techniques, and planting and seeding recommendations (for example, Bentrup and Hoag 1998; Carlson and McArthur 1985; Fulbright and others 1982; Landis and Simonich 1982; Link 1993; McArthur and others 1978; Monsen and Shaw 1983; Monsen and Stevens, in review; Redente and others 1982; Rose and others 1998; Smith and Smith n.d.; Stevens and others 1996; Vories 1980; Wark and others 1995; Wasser 1982; Young and Young 1986). Similar information is becoming more available on the Internet. Examples include the Plants Database, a source of information on plants of the United States, including their use as plant materials (USDA NRCS 2000); Vegspec, a web-based decision support system for planning revegetation programs (USDA NRCS and others 2000); the Plant Materials Program, which describes USDA NRCS Plant Materials and their availability (USDA NRCS 2000); the Native Plants Network with protocols for propagation of native plants (University of Idaho 2000); the National Tree Seed Laboratory (USDA Forest Service 2000b); Grass Varieties in the United States (Alderson and Sharp 1994); and the State and Private Forestry Reforestation, Nurseries and Genetic Resources Program with information on nursery management and propagation of forest and conservation seedlings (USDA Forest Service 2000c). The Native Plants Journal, first published by the USDA Forest Service and the University of Idaho in January 2000 (University of Idaho 2000) features papers on plant propagation and use of native plants.

Conclusions

Monsen and Christensen's 1976 paper listed five areas for future plant materials research emphasis: (1) further study of the range of adaptability of species and ecotypes being used; (2) selection and development of additional species and ecotypes for revegetation uses; (3) development of a dependable supply of high-quality seeds and transplanting stock; (4) improvements in site preparation and planting procedures for the establishment of shrubs on rangelands; and (5) reduction of plant losses to insects and diseases. All of these themes remain important today. The last 25 years have seen important advances in all phases of revegetation science and applications. Rather than focusing on specific uses, the aim of revegetation now is to restore functional plant communities dominated by adapted native species where practical. Additional work is needed to provide the research data and verification procedures to ensure selection of adapted seed sources and maintain their identity. To accomplish true restorations, there is a need to develop revegetation technology for additional species. Seed production guides are generally provided with cultivar releases, but seed production and propagation techniques are needed to provide adequate seed and plant supplies of numerous other species (Jones 1997a; McArthur and Young 1999). Germination and viability procedures must be developed for more species, and new approaches taken to reduce inconsistencies in laboratory test results (Kitchen 2001). Adequate storage facilities are needed to permit accumulation of seeds in good production years, improve availability of commonly used species and sources, and stabilize the seed industry. Additional site preparation and seeding technology and equipment are required to provide weed control and permit seeding of diverse seed mixtures. Understanding of establishment requirements and species interactions is needed to successfully reestablish diverse plant communities.

References

Alderson, J.; Sharp, W. C. 1994. Grass varieties in the United States. Agric. Handb. 170. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service. 296 p. [Also online]. Available: http://www.forages.css.orst.edu/Topics/Species/Grasses/Grass_Varieties/index.html

AOSA (Association of Official Seed Analysts). 2000. Rules for testing seeds. Journal of Seed Technology. 12: 1–126.

AOSA (Association of Official Seed Analysts). [In press]. Native plant symposium proceedings. Seed Technology.

AOSCA. 1997. Seed certification tags and nomenclature for plant germplasm types. In: Genetic and crop standards of the Association of Official Seed Certifying Agencies. Beltsville, MD: Association of Official Seed Certifying Agencies: 1-12–1-14.

Bakker, J. D. 1999. Transferability of native shrubs. In: Proceedings of the 1995, 1996, 1997 Forest Nursery Association of British Columbia meetings. Forest Nursery Association of B.C.: 176–179.

Basile, Joseph V.; Holmgren, Ralph C. 1955. Artificial revegetation studies on depleted big game winter ranges in Idaho. Job Prog. Rep. W111-R-1. Boise, ID: Idaho Fish and Game Department. 23 p.

Basile, Joseph V.; Holmgren, Ralph C. 1957. Artificial revegetation studies on depleted big game winter ranges in Idaho. Job Prog. Rep. W111-R-3. Boise, ID: Idaho Fish and Game Department. 11 p.

Beetle, A. A. 1960. A study of sagebrush, the section *Tridentatae* of *Artemisia*. Bull. 368. Laramie, WY: University of Wyoming Agricultural Experiment Station. 83 p.

Bell, S. S.; Fonseca, M. S.; Motten, L. B. 1997. Linking restoration and landscape ecology. Restoration Ecology. 5(45): 318–323.

Belnap, J. 1995. Genetic integrity: why do we care? An overview of the issues. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 265–295.

Bentrup, G.; Hoag, J. C. 1998. The practical streambank bioengineering guide. Aberdeen, ID: U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Center. 165 p.

Blaisdell, J. P. 1972. Needs and opportunities for shrub research in the Western United States. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., tech. eds. Wildland shrubs—their biology and utilization; 1971 July 12–16; Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 409–413.

Blauer, A. C.; Plummer, A. P.; McArthur, E. D.; Giunta, B. C. 1976. Characteristics and hybridization of important Intermountain shrubs. II. Chenopod family. Res. Pap. INT-177. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 42 p.

Blauer, A. C.; Plummer, A. P.; McArthur, E. D.; Stevens, R.; Giunta, B. C. 1975. Characteristics and hybridization of important Intermountain shrubs. I. Rose family. Res. Pap. INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 36 p.

Borman, M. M. 1996. Riparian rehabilitation with native vegetation. In: Edge, W. D.; Olson-Edge, S. L., eds. Proceedings of a symposium on sustaining rangeland ecosystems; 1994 August 29–31; La Grande, OR. Special Rep. 953. Corvallis, OR: Oregon State University: 45–51.

Box, T. W. 1986. Capstone address. Crested wheatgrass: its values, problems and myths; where now? In: Johnson, K. L., ed. Crested wheatgrass: its values, problems and myths; symposium proceedings; 1983 October 3–7; Logan, UT. Logan: Utah State University: 343–345.

Carlson, J. R. 1992. Selection, production, and use of riparian plant materials for the Western United States. In: Landis, T. D., comp. Proceedings Intermountain Forest Nursery Association; 1991 August 12–16; Park City, UT. Gen. Tech. Rep. RM-211. Fort Collins, CO: U.S. Department of Agriculture, Forest Service: 55–67.

Carlson, J. R.; McArthur, E. D., eds. 1985. Symposium on range plant improvement. In: Proceedings: selected papers presented at the 38th annual meeting of the Society for Range Management; 1985 February 14; Salt Lake City, UT. Denver, CO: Society for Range Management: 107–220.

Carter, J. 1977a. Executive Order 11987—Exotic organisms. Federal Register. 42: 26949.

Carter, J. 1977b. Executive Order 11988—Floodplain management. Federal Register. 42: 26951.

Carter, J. 1977c. Executive Order 11990—Protection of wetlands. Federal Register. 42: 26961.

Clark, M.; McLean, A. 1979. Growth of lodgepole pine seedlings in competition with grass. Res. Note 86. Victoria, Canada: Ministry of Forests, British Columbia Forest Service, Research Branch. 13 p.

Clinton, W. J. 1994. Executive Memorandum on environmentally and economically beneficial landscape practices on Federal landscaped grounds. Federal Register. 60: 40837.

Clinton, W. J. 1999. Executive Order 13112—Invasive species. Federal Register. 64: 6183.

Copeland, L. O.; McDonald, M. B. 1985. Principles of seed science and technology. 2d ed. Minneapolis, MN: Burgess Publishing Company. 321 p.

Cornell Law School, Legal Information Institute, comps. 2000. U.S. Code [Online]. Ithaca, NY: Cornell Law School, Legal Information Institute [Online]. Available: http://www4.law.cornell.edu/uscode/unframed

Currans, S. P.; Kitchen, S. G.; Lambert, S. M. 1997. Ensuring identity and quality of native seeds. In: Shaw, N. L.; Roundy, B. A., comps. Proceedings: using seeds of native species on rangelands; 1997 February 16–21; Rapid City, SD. Gen. Tech. Rep. INT-GTR-372. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 17–20.

Davis, C. 1997. Politics and public rangeland policy. In: Davis, Charles, ed. Western public lands and environmental politics. Boulder, CO: Westview Press: 74–94.

Davis, J. N. 1983. Performance comparisons among populations of bitterbrush, cliffrose, and bitterbrush-cliffrose hybrid crosses on study sites throughout Utah. In: Tiedemann, A. R.; Johnson, K. L., comps. Proceedings on research and management of bitterbrush and cliffrose in Western North America; 1982 April 13–15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 38–44.

DePuit, E. J.; Redente, E. F. 1988. Manipulation of ecosystem dynamics on reconstructed semiarid lands. In: Allen, E. B., ed. The reconstruction of disturbed arid lands. Boulder, CO: Westview Press Inc.: 162–204.

Drobnick, R.; Plummer, A. P. 1966. Progress in browse hybridization in Utah. Proceedings: annual conference of Western State Game and Fish Commissioners. 46: 203–211.

Edgerton, P. J; Geist, J. M.; Williams, W. G. 1983. Sources of antelope bitterbrush in northeast Oregon. In: Tiedemann, A. R.; Johnson, K. L., comps. Proceedings—research and management of bitterbrush and cliffrose in Western North America; 1982 April 13–15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 45–54.

Ehrenfeld, J. G.; Toth, L. A. 1997. Restoration ecology and the ecosystem perspective. Restoration Ecology. 5(4): 307–317.

Elliot, K.; White, A. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Science. 33: 356–366.

Englert, J. M.; Scheetz, J. G.; White, R. S. 1999. Improved conservation plant materials released by NRCS and cooperators through September 1999. Beltsville, MD: U.S. Department of Agriculture, Natural Resources Conservation Service. 49 p.

Entwistle, P. G.; DeBolt, A. M.; Kaltenecker, J. H.; Steenhof, K, comps. 2000. Proceedings: sagebrush steppe ecosystems symposium; 1999 June 21–23; Boise, ID. BLM/ID/PT-001001+1150.

Boise, ID: U.S. Department of the Interior, Bureau of Land Management. 145 p.

Ferguson, R. B.; Monsen, S. B. 1974. Research with containerized shrubs and forbs in southern Idaho. In: Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings of the North American containerized forest tree seedling symposium; 1974 August 26–29; Denver, CO. Publ. 68. Great Plains Agricultural Council: 349–358.

Flessner, T. R.; Darris, D. C.; Lambert, S. M. 1992. Seed source evaluation of four native riparian shrubs for streambank rehabilitation in the Pacific Northwest. In: Clary, W. P.; McArthur, E. D.; Bedunah, D.; Wambolt, C. L., comps. Symposium on ecology and management of riparian shrub communities; 1991 May 29–31; Sun Valley, ID. Gen. Tech. Rep. INT-289. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 155–162.

Forsling, C. L.; Dayton, W. A. 1931. Artificial reseeding on Western mountain range lands. Circ. 178. Washington, DC: U.S. Department of Agriculture, Forest Service. 48 p.

Fritz, Cindy. 2001. [Personal communication]. January 24. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Lower Snake River District.

Fulbright, T. E.; Redente, E. F.; Hargis, N. E. 1982. Growing Colorado plants from seed: a state of the art. Vol II: Grasses and grasslike plants. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 80 p.

Giunta, B. C.; Stevens, R.; Jorgensen, K. R.; Plummer, A. P. 1978. Antelope bitterbrush—an important wildland shrub. Publ. 78-12. Salt Lake City, UT: Utah State Division of Wildlife Resources. 48 p.

Goodwin, C. N.; Hawkins, C. P.; Kershner, J. L. 1997. Riparian restoration in the Western United States: an overview and perspective. Restoration Ecology. 5(45): 4–14.

Grabe, D. F., ed. 1970. Tetrazolium testing handbook for agricultural seeds. Contribution 29. Handbook on seed testing. Lincoln, NE: Association of Official Seed Analysts. 62 p.

Gutknecht, K. W. 1992. Native vs. introduced species: the new range war. Utah Science. 53: 69–78.

Haas, R. 2001. [Letter to Nancy Shaw]. January 31. One leaf. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID.

Harper-Lore, Bonnie L., ed. 1999. Roadside use of native plants. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. 665 p.

Harper-Lore, Bonnie L. 2001. [Letter to Nancy Shaw]. January 31. Two leaves. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID.

Hawkins, C. P.; Bartz, K. L.; Neale, C. M. U. 1997. Vulnerability of riparian vegetation to catastrophic flooding: implications for riparian restoration. Restoration Ecology. 5(45): 75–84.

Heit, C. E. 1967. Propagation from seed. Part II: Storage of deciduous tree and shrub seeds. American Nurseryman. 9: 12–13, 86–94.

Heit, C. E. 1968. Propagation from seed. Part 15: Fall planting of shrub seeds for successful seedling production. American Nurseryman. 10: 8–10, 70–80.

Heit, C. E. 1971. Propagation from seed. Part 22: Testing and growing western desert and mountain shrub species. American Nurseryman. 13(10): 10–12, 76–89.

Hoag, J. C. 1995. Establishment techniques for woody vegetation riparian zones of the arid and semi-arid West. In: Growing a sustainable future: proceedings: fourth North American agroforestry conference; 1995 July 23–28; Boise, ID. Moscow, ID: University of Idaho: 124–125.

Holmgren, R. C. 1956. Competition between annuals and young bitterbrush (*Purshia tridentata*) in Idaho. Ecology. 37: 370–377.

Holmgren, R. C.; Basile, J. V. 1959. Improving southern Idaho deer winter ranges by artificial revegetation. Wildlife Bull. 3. Boise, ID: Idaho Department of Fish and Game. 61 p.

Hubbard, R. L. 1962. The place of browse seeding in game range management. In: Twenty-seventh North American wildland natural resources conference transactions: 394–401.

Hubbard, R. L.; Nord, E. C.; Brown, L. L. 1959. Bitterbrush reseeding—a tool for the game range manager. Misc. Pap. 39. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 14 p.

Hughes, D. 1996. Restoring native riparian vegetation. In: Shaw, D. W.; Finch, D. M., tech. coords. Desired future conditions for Southwestern riparian ecosystems: bringing interests and concerns together; 1995 September 18–22; Albuquerque, NM. Gen. Tech. Rep. RM-GTR-272. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 262–264.

Jelinski, D. E. 1997. On genes and geography: a landscape perspective on genetic variation in natural plant populations. Landscape and Urban Planning. 39: 11–23.

Johnson, K. L., ed. 1986. Crested wheatgrass: its values, problems and myths: symposium proceedings; 1983 October 3–7; Logan, UT. Logan: Utah State University. 348 p.

Jones, A.; Smith, B. N.; Hansen, L. D.; Monsen, S. B.; Stevens, R. 1999. Calorimetric study of the effects of water and temperature on the respiration and growth of small burnet and alfalfa. In: Monsen, S. B.; Stevens, R., comps. Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997 September 15–18; Provo, UT. Proceedings RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 51–54.

Jones, T. A. 1997a. The expanding potential of native grass seed production in Western North America. In: Landis, T. D.; Thompson, J. R., tech. coords. National proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 89–92.

Jones, T. A. 1997b. Genetic considerations for native plant materials. In: Shaw, Nancy L.; Roundy, Bruce A., comps. Proceedings: using seeds of native species on rangelands; 1997 February 16–21; Rapid City, SD. Gen. Tech. Rep. INT-GTR-372. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 22–25.

Jones, T. A.; Johnson, J. A. 1998. Integrating genetic concepts into planning rangeland seedings. Journal of Range Management. 51: 594–606.

Jordan, G. L. [n.d.]. Range seeding and brush management. T81121. Tucson, AZ: University of Arizona Agriculture Experiment Station, Cooperative Extension Service. 88 p.

Kauffman, J. B.; Krueger, W. C. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management. 37: 430–437.

Kitchen, S. 2000. [Letter to Nancy Shaw]. December 19. One leaf. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID.

Kitchen, Stanley G. 2001. Intra-specific variability in germination behavior and seed testing protocols: the challenge of intermountain species. Seed Technology. 23: 68–77

Lambert, S. 1995. Native plants recommended for wetland/riparian plantings in the Pacific Northwest. Tech. Notes, Plant Materials 28. Spokane, WA. U.S. Department of Agriculture, Natural Resources Conservation Service. 4 p.

Lambert, S. 1999. Washington and Oregon guide for conservation seedings and plantings. Pullman, WA: U.S. Department of Agriculture, Natural Resources Conservation Service. 126 p.

Landers, D. H. 1997. Riparian restoration: current status and the reach to the future. Restoration Ecology. 5(45): 113–121.

Landis, T. D.; Simonich, E. J. 1982. Producing native plants as container seedlings. In: Murphy, P. M., comp. The challenge of producing native plants for the Intermountain area; proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8–11; Las Vegas, NV. Gen. Tech. Rep. INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 16–25.

Larson, J. 1982. History of the Vegetative Rehabilitation and Equipment Workshop (VREW) 1946–1981. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center. 66 p.

Linhart, Y. B. 1995. Restoration, revegetation, and the importance of genetic and evolutionary perspectives. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, K. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 271–287.

Link, E., ed. 1993. Native plant propagation techniques for National Parks. East Lansing, MI: Rose Lake Plant Materials Center. 240 p.

Loomis, J. B. 1993. Integrated public land management: principles and applications to National Forests, Parks, Wildlife Refuges and BLM lands. New York: Columbia University Press. 474 p.

Mahalovich, M. 2001a. Seed transfer guidelines for antelope bitterbrush, Stansbury cliff rose and its hybrid, desert bitterbrush. Draft manuscript on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Moscow, ID. 2 p.

Mahalovich, M. 2001b. Seed transfer guidelines for sagebrush. Draft manuscript on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Moscow, ID. 4 p.

Mathews, W. L. 1986. Early use of crested wheatgrass seedings in halogeton control. In: Johnson, K. L., ed. Crested wheatgrass: its values, problems and myths: symposium proceedings; 1983 October 3–7; Logan, UT. Logan: Utah State University: 27–28.

McArthur, E. D. 1992. In memoriam—A. Perry Plummer (1911–1991): teacher, naturalist, range scientist. Great Basin Naturalist. 52: 1–10.

McArthur, E. D.; Blauer, A. C.; Plummer, A. P.; Stevens, R. 1979. Characteristics and hybridization of important Intermountain shrubs. III. Sunflower family. Res. Pap. INT-22. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 82 p.

McArthur, E. D.; Freeman, D. C.; Graham, J. H.; Wang, H.; Sanderson, S. C.; Monaco, T. A.; Smith, B. N. 1998. Narrow hybrid zone between two subspecies of big sagebrush (*Artemisia tridentata*: Asteraceae). VI. Respiration and water potential. Canadian Journal of Botany. 76: 567–574.

McArthur, E. D.; Plummer, A. P.; Van Epps, G. A.; Freeman, D. C.; Jorgensen, K. R. 1978. Producing fourwing saltbush in seed orchards. In: Hyder, D. N., ed. Proceedings of the First International Rangeland Congress; 1978 August 14–18; Denver, CO. Denver: Society for Range Management: 406–410.

McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., comps. 1990. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 351 p.

McArthur, E. D.; Young, S. A. 1999. Development of native seed supplies to support restoration of pinyon-juniper sites. In: Monsen, S. B.; Stevens, R., comps. Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997 September 15–18; Provo, UT. Proc. RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 327–330.

McKell, C. M; Blaisdell, J. P.; Goodin, J. R., tech. eds. 1972. Wildland shrubs—their biology and utilization; 1971 July 12–16; Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 494 p.

Meeuwig, R. O. 1960. Watersheds A and B—a study of surface runoff and erosion in the subalpine zone of central Utah. Journal of Forestry. 58: 556–560.

Meyer, S. E.; Nelson, D. L.; Clement, S.; Paulsen, A. 2000. Exploring the potential for biocontrol of cheatgrass with the headsmut pathogen. In: Entwhistle, P. G.; DeBolt, A. M.; Kaltenecker, J. H.; Steenhof, K., comps. Proceedings: sagebrush steppe ecosystem symposium; 1999 June 23–25; Boise, ID. BLM/ID/PT-001001+1150. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office: 70–72.

Millar, C. I.; Libby, W. J. 1989. Disneyland or native ecosystem: genetics and the restorationist. Restoration and Management Notes. 7: 18–24.

Mitsch, W. J.; Gosselink, J. G. 1993. Wetlands. 2d ed. New York: Van Nostrand Rheinland. 722 p.

Monaco, T. A.; Smith, B. N.; Hemming D. J.; Hansen L. B.; Monsen, S. B.; Carlson, S. L. 1996. Dark respiration comparisons of forbs and grasses from common gardens. In: Barrow, J. R.; McArthur, E. D.; Sosebee, R. E.; Tausch, R. J., comps. Proceedings: shrubland ecosystem dynamics in a changing environment; 1995 May 23–25; Las Cruces, NM. Gen. Tech. Rep. INT-GTR-338. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 210–213.

Monsen, S. B. 1975. Selecting plants to rehabilitate disturbed areas. In: Campbell, R. S.; Herbal, C. H., eds. Improved range plants. Denver, CO: Society for Range Management: 76–90.

Monsen, S. B.; Christensen, D. R. 1976. The use of shrubs in rehabilitation of rangelands in the Intermountain Region. In: Stutz, H. C., ed. Proceedings, symposium and workshop on the occasion of the dedication of the U.S. Forest Service Shrub Sciences Laboratory; 1975 November 6–7; Provo, UT. Provo, UT: Brigham Young University: 72–119.

Monsen, S. B.; Kitchen, S. G., comps. 1994. Proceedings—ecology and management of annual rangelands; 1992 May 18–21; Boise, ID. Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 416 p.

Monsen, S. B.; McArthur, E. D. 1995. Implications of early Intermountain range and watershed restoration practices. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 16–25.

Monsen, S. B.; Shaw, N. L., comps. 1983. Managing Intermountain rangelands—improvement of range and wildlife habitats: proceedings of a symposium; 1981 September 15–17; Twin Falls, ID; 1982 June 22–24, Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 194 p.

Monsen, S. B; Stevens, R. [In review]. Restoring Western ranges and wildlands.

Munda, B. D.; Smith, S. E. 1995. Genetic variation and revegetation strategies for desert rangeland ecosystems. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 288–291.

Nord, E. C. 1965. Autecology of bitterbrush in California. Ecological Monographs. 35: 307–334.

Office of Management and Budget. 2001. Budget of the United States Government [online]. Available: http://w3.access.gpo.gov.usbudget/fy2001/maindown.html

Ogle, D. G.; Hoag, J. C.; Scianna, J. D. 2000. User's guide to description, propagation and establishment of native shrubs and trees for riparian areas in the Intermountain West. Tech. Notes Plant Materials 32. Boise, ID: U.S. Department of Agriculture, Natural Resources Conservation Service. 22 p.

Pellant, M. 1990. The cheatgrass-wildfire cycle—are there any solutions? In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., comps. 1990. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 11–18.

Pellant, M.; Monsen, Stephen B. 1993. Rehabilitation on public rangelands in Idaho, USA: a change in emphasis from grass monocultures. In: Proceedings of the XVII International Grassland Congress; 1993 February 8–21; Palmerston North, New Zealand. Palmerston North, New Zealand: New Zealand Grassland Association and others: 778–779.

Pellant, M.; Hall, C. 1994. Distribution of two exotic grasses on Intermountain rangelands: status in 1992. In: Monsen, Stephen B.; Kitchen, Stanley G., comps. 1994. Proceedings—ecology and management of annual rangelands; 1992 May 18–21; Boise, ID. Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 109–112.

Pellant, M.; Kaltenecker, J.; Jirik, S. 1999. Use of OUST(R) herbicide to control cheatgrass in the northern Great Basin. In: Monsen, Stephen B.; Stevens, Richard, comps. 1999. Proceedings: ecology and management of pinyon-juniper communities within the Interior West; 1997 September 15–18; Provo, UT. Proc. RMRS-P-9. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 322–326.

Peters, J., ed. 2000. Tetrazolium testing handbook. Contribution 29. Handbook on seed testing. First revision. Lincoln, NE: Association of Official Seed Analysts, Inc. 21 p.

Plant Conservation Alliance. 2001. Plant Conservation Alliance [Online]. Available: http://www.nps.gov/plants.

Plummer, A. P. 1972. Selection. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., tech. eds. Wildland shrubs—their biology and utilization; 1971 July 12–16; Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 121–126.

Plummer, A. P. 1977. Revegetation of disturbed Intermountain area sites. In: Thames, J. L., ed. Reclamation and use of disturbed land in the Southwest. Tucson, AZ: University of Arizona Press: 302–339.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. 1968. Restoring big game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Division of Fish and Game. 183 p.

Plummer, A. P.; Hull, A. C., Jr.; Stewart, G.; Robertson, J. H. 1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U.S. Department of Agriculture Handb. 71. Washington, DC: U.S. Government Printing Office. 73 p.

Plummer, A. P.; Jensen, R. L.; Stapley, H. D. 1957. Job completion report for game forage revegetation project W-32-R-2. Information Bull. 1946-57. Salt Lake City, UT: Utah State Department of Fish and Game. 128 p.

Plummer, A. P.; Stewart, G. 1944. Seeding grass on deteriorated aspen range. Res. Pap. INT-11. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 6 p.

Powell, G.; Pitt, M.; Wikeem, B. 1994. Effect of forage seeding on early growth and survival of lodgepole pine. Journal of Range Management. 47: 379–384.

Pyke, D. A. 1996. Rangeland seedings and plantings: exotics or natives? In: Edge, W. D.; Olson-Edge, S. L., eds. Proceedings—sustaining rangeland ecosystems symposium; 1994 August 29–31; La Grande, OR. SR953. Corvallis, OR: Oregon State University: 32–44.

Redente, E. F.; Keammerer, W. R. 1999. Use of native plants for mined land reclamation. In: Eldridge, D.; Freudenberger, D., eds. Proceedings of the VI International Rangeland Congress: people and rangelands building the future; 1999 July 19–23; Townsville, Queensland, Australia. Aitkenville, Queensland, Australia. 2: 957–961.

Redente, E. F; Ogle, P. R.; Hargis, N. E. 1982. Growing Colorado plants from seed: a state of the art. Vol. III: Forbs. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 141 p.

Rice, K. J. 1996. What is native? In: Edge, W. D.; Olson-Edge, S. L., eds. Proceedings of a symposium on sustaining rangeland ecosystems; 1994 August 29–31; La Grande, OR. Special Rep. 953. Corvallis: Oregon State University: 27–29.

Richards, R. T.; Chambers, J.; Ross, C. 1998. Native seed policy and practice—a viewpoint. Journal of Range Management. 52(4): 625–632.

Robichaud, P. R.; Beyers, J. L.; Neary, D. G. 2000. Evaluating the effectiveness of postfire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 85 p.

Rose, R.; Chachulski, C. E. C.; Haase, D. L. 1998. Propagation of Pacific Northwest native plants. Corvallis: Oregon State University Press. 248 p.

Rosentreter, R.; Jorgensen, R. 1986. Restoring winter game ranges in southern Idaho. Idaho BLM Tech. Bull. 86-3. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office. 26 p.

Roundy, B. A. 1996. Revegetation for wildlife. In: Krausman, P. R., ed. Rangeland wildlife. Denver, CO: Society for Range Management: 355–368.

Roundy, B. A.; Call, C. A. 1988. Revegetation of arid and semiarid rangelands. In: Tueller, P. T., ed. Vegetation science applications to rangeland analysis and management. Boston, MA: Kluwer Academic Publishers: 607–635.

Roundy, B. A.; Shaw, N. L.; Booth, D. T. 1997. Using native seeds on rangelands. In: Shaw, N. L.; Roundy, B. A., comps. Proceedings: using seeds of native species on rangelands; 1997 February 16–21; Rapid City, SD. Gen. Tech. Rep. INT-GTR-372. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 1–8.

Schopmeyer, C. S., tech. coord. 1974. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service. 883 p.

Shaw, N. L.; Monsen, S. B. 1983. Phenology and growth habits of nine antelope bitterbrush, desert bitterbrush, Stansbury cliffrose, and Apache-plume accessions. In: Tiedemann, A. R.; Johnson, K. L., comps. Proceedings—research and management of bitterbrush and cliffrose in Western North America; 1982 April 13–15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 55–69.

Shaw, N. L.; Monsen, S. B. 2000. Controlling annual grasses with Oust® herbicide. In: Entwistle, P. G.; DeBolt, A. M.; Kaltenecker, J. H., Steenhof, K., comps. Proceedings: sagebrush steppe ecosystem symposium; 1999 June 23–25; Boise, ID. BLM/ID/PT-001001+1150. Boise, ID: U.S. Department of the Interior, Bureau of Land Management, Idaho State Office: 66–69.

Sheley, Roger L.; Petroff, Janet K. 1999. Biology and management of noxious rangeland weeds. Corvallis, OR: Oregon State University Press. 438 p.

Skovlin, J. M. 1984. Impacts of grazing on wetlands and riparian habitat: a review of our knowledge. In: Developing strategies for rangeland management. Boulder, CO: Westview Press: 1001–1103.

Smith, B. N.; Monaco, T. A.; Hemming, D. J. B.; Hansen, L. D.; Criddle, R. S. 1996. The relation between respiration and growth rates of accessions of plants of the Great Basin, United States. Russian Journal of Plant Physiology. 43: 821–825.

Smith, S. R., Jr.; Smith, S. [n.d.]. Native grass seed production manual (including selected forbs). U.S. Department of Agriculture, Natural Resources Conservation Service, Plant Materials Program; Ducks Unlimited Canada; Manitoba Forage Seed Association; University of Manitoba. 155 p.

Stebbins, G. L. 1950. Variation and evolution in plants. New York: Columbia University Press. 643 p.

Stein, W. I.; Danielson, R.; Shaw, N.; Wolff, S.; Gerdes, D. 1986. User's guide for seeds of Western trees and shrubs. Gen. Tech. Rep. PNW-193. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p.

Stevens, R.; Giunta, B. C.; Jorgensen, K. R.; Plummer, A. P. 1977. Winterfat. Publ. 77-2. Salt Lake City, UT: Utah State Division of Wildlife Resources. 41 p.

Stevens, R.; Jorgensen, K. R.; Young, S. A.; Monsen, S. B. 1996. Forb and shrub seed production guide for Utah. AG501. Logan: Utah State University Extension Service. 51 p.

Stutz, H. C., ed. 1975. Proceedings: symposium and workshop wildland shrubs; 1975 November 6–7; Provo, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 168 p.

Stutz, H. C. 1983. Broad gene pools required for disturbed lands. In: Aldon, E. F.; Oaks, W. R., eds. Reclamation of mined lands in the Southwest—a symposium; 1982 October 20–22; Albuquerque, NM. Albuquerque, NM: Soil Conservation Society of America, New Mexico Chapter: 113–118.

Stutz, H. C.; Melby, J. M.; Livingston, G. K. 1975. Evolutionary studies of *Atriplex*: a relic gigas diploid population of *Atriplex canescens*. American Journal of Botany. 62: 236–245.

Stutz; H. C.; Thomas, L. K. 1964. Hybridization and introgression in *Cowania* and *Purshia*. Evolution. 18: 183–195.

Swanson, S. 1988. Riparian values as a focus for range management and vegetation science. In: Tueller, P. T., ed. Vegetation science applications for rangeland analysis and management. Boston, MA: Kluwer Academic Publishers: 425–445.

Thomas, J. W.; Maser, C.; Rodiek, J. E. 1979. Wildlife habitats in managed rangelands. The Great Basin of southeastern Oregon: riparian zones. Gen. Tech. Rep. PNW-80. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Tiedemann, A. R.; Johnson, K. L., comps. 1983. Proceedings—research and management of bitterbrush and cliffrose in Western North America; 1982 April 13–15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 279 p.

Tiedemann, A. R.; McArthur, E. D.; Stutz, H. C.; Stevens, R.; Johnson, K. L., comps. 1984. Proceedings—symposium on the biology of

Atriplex and related chenopods; 1983 May 2–6; Provo, UT. Gen. Tech. Rep. INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 309 p.

Tzoumis, K. A. 1998. Wetland policymaking in the U.S. Congress from 1789 to 1995. Wetlands. 18(3): 447–459.

U.S. Department of Agriculture, Farm Service Agency. 2001a. Conservation Reserve Program [Online]. Available: http://www.fsa.usda.gov/dafp/cepd/crpinfo.htm

U.S. Department of Agriculture, Farm Service Agency. 2001b. CRP monthly active contract fill upload [Online]. Available: http://www.fsa.usda.gov/crpstorpt/12approved/r1pracyr/r1pracyr2.htm

U.S. Department of Agriculture, Forest Service. 1936. The Western range. Washington, DC: 74th Congress, 2d session, Senate Document 199. 620 p.

U.S. Department of Agriculture, Forest Service. 1979. User guide to vegetation. Gen. Tech. Rep. INT-64. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 85 p.

U.S. Department of Agriculture, Forest Service. 2000a. Guidelines for revegetation for the Arapaho-Roosevelt, Grand Mesa-Uncompahgre-Gunnison, and Medicine Bow-Routt National Forests, and Pawnee and Thunder Basin National Grasslands. Unpublished paper on file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID. 25 p.

U.S. Department of Agriculture, Forest Service. 2000b. National Tree Seed Laboratory [Online]. Available: http://ntsl.net

U.S. Department of Agriculture, Forest Service. 2000c. Reforestation, nurseries and genetic resources [Online]. Available: http://www.na.fs.fed.us/spfo/rngr

U.S. Department of Agriculture, Forest Service. 2000d. Title 2500—Watershed and air management. Forest Service Manual. Washington, DC: U.S. Department of Agriculture, Forest Service. 30 p.

U.S. Department of Agriculture, Forest Service. 2000e. Woody plant seed manual. [Online]. Available: http://www.wpsm.net

U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Surface Environment and Mining Program. [n. d.]. Native shrub production project: Coeur d'Alene Nursery. Billings, MT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 40 p.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2000. The PLANTS database [Online]. Baton Rouge, LA: National Plant Data Center. Available: http://plants.usda.gov/plants

U.S. Department of Agriculture, National Resources Conservation Service; U.S. Geological Survey, Biological Resources Division, Forest and Rangeland Ecosystem Science Center; U.S. Army Corps of Engineers, Construction Engineering Research Laboratories. 2000. VEGSPEC [Online]. Available: http://ironwood.itc.nrcs.usda.gov/Netdynamics/Vegspec/pages

U.S. Department of the Interior, Bureau of Land Management. 1996. Policy on the use of native plant materials in California. [Letter to AFOs]. December 19. 9 leaves. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID; RWU 4202 files.

U.S. Department of the Interior, Bureau of Land Management. 1998. Emergency fire rehabilitation handbook H-1742. Washington, DC: U.S. Department of the Interior, Bureau of Land Management. 43 p.

U.S. Department of the Interior, Bureau of Land Management. 2000a. Bureau of Land Management National Office of Fire and Aviation [Online]. Available: http://www.fire.blm.gov/index.htm

U.S. Department of the Interior, Bureau of Land Management. 2000b. The Great Basin: healing the land. Washington, DC: U.S. Department of the Interior, Bureau of Land Management.

U.S. Department of the Interior, Bureau of Land Management. 2001. USDI-BLM seed purchases. Unpublished data on file at: USDI Bureau of Land Management, Denver, CO. [n.p.].

University of Idaho. 2000. Forest research nursery [Online]. Available: http://www.uidaho.edu/seedlings/index.htm

Vallentine, J. F. 1989. Range developments and improvements. 3d ed. San Diego, CA: Academic Press, Inc. 524 p.

Vankus, V. 1997. The tetrazolium estimated viability for seeds of native plants. In: Landis, T. D.; Thompson, J. R., tech. coords. National proceedings: Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-419. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 57–62.

Vories, K. C. 1980. Growing Colorado plants from seed: a state of the art. Vol. I: Shrubs. Gen. Tech. Rep. INT-103. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 80 p.

Walker, S. 2000. Seeding records. Unpublished data on file at: Utah Division of Wildlife Resources, Ephraim, UT. [n p.].

Walker, S. C.; Stevens, R.; Monsen, S. B.; Jorgensen, K. R. 1995. Interaction between native and seeded introduced grasses for 23 years following chaining of juniper-pinyon woodlands. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, D. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 372–380.

Wark, D. B.; Poole, W. R.; Arnott, R. G.; Moats, L. R.; Wetter, L. 1995. Revegetating with native grasses. Stonewall, Manitoba, Canada: Ducks Unlimited, Canada.

Wasser, C. H. 1982. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 347 p.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River Plains; ecological and management implications. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., comps. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 1–7.

Whisenant, S. G. 1999. Repairing damaged wildlands: a process-oriented landscape scale approach. Cambridge, U.K.: Cambridge University Press. 224 p.

White, T. A.; Blair, C. L.; McDonald, K. B. 1992. Wetland replacement: the art and science of renewing damaged ecosystems. Renewable Resources Journal. Winter: 18–24.

Willard, D. E.; Reed, R. B. 1986. The use of native species to restore and create wetland habitat for mitigation. In: Kusler, J. A.; Quammen, M. L.; Brooks, G., eds. Proceedings national wetland symposium: mitigation of effects and losses; 1986 October 8–10; New Orleans, LA. Berne, NY: Association of State Wetland Managers: 340–342.

Young, J. A.; Evans, R. A. 1986. History of crested wheatgrass in the Intermountain area. In: Johnson, K. L., ed. Crested wheatgrass: its values, problems, and myths: symposium proceedings; 1983 October 3–7; Logan, UT. Logan: Utah State University: 21–25.

Young, J. A.; Evans, R. A.; Eckert, R. E., Jr.; Kay, B. L. 1987. Cheatgrass. Rangelands. 9: 266–270.

Young, J. A.; Young, C. G. 1986. Collecting, processing and germinating seeds of wildland plants. Portland, OR: Timber Press. 236 p.

Young, J. A.; Young, C. G. 1992. Seeds of woody plants in North America. Portland, OR: Dioscorides Press. 407 p.

Young, S. A. 1995. Verification of germplasm origin and genetic status by seed certification agencies. In: Roundy, B. A.; McArthur, E. D.; Haley, J. S.; Mann, K. K., comps. Proceedings: wildland shrub and arid land restoration symposium; 1993 October 19–21; Las Vegas, NV. Gen. Tech. Rep. INT-GTR-315. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 293–295.

Young, S. A. 1996. Alternative germplasm release procedures for producing certified seed. Seed World. July: 14–15.

Young, S. A. 2001. [Letter to Nancy Shaw]. January 26. One leaf. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Forestry Sciences Laboratory, Boise, ID.

Young, S. A.; Kitchen, S. G.; Armstong, J.; Watson, V. H. 1995. A.O.S.C.A. approves certification guidelines for wildland collected seed. Seed World. 133: 20–21.