Grass cultivars: Their origins, development, and use on national forests and grasslands in the Pacific Northwest

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Abstract

Grass cultivars are a distinct subset of a species, often intentionally bred to behave uniformly and predictably when grown in an environment to which the species is adapted. A cultivar, also called a variety or a release, is given a unique trade name chosen by the breeder. These single-word names—such as 'Arlington', 'Bromar' or 'Secar'—most often relate to the place of origin, species name, cultivar characteristics, or an individual involved in the process. Grass cultivars have been used in large quantities, often without an assessment of the consequences. Since grass cultivars vary in their origins, development history, and effects on native plant populations, it is important to know more than the brand name and the species name when considering a seed source for revegetation. Although a cultivar has been developed for particular uses or appears to be adapted to a wide range of conditions, the material may not necessarily be suitable or optimal for all situations. Use of such material may have long-term and possibly irreversible genetic and ecological effects. Therefore it is essential to have a thorough understanding of plant material genetic origins, biological attributes, and level of compatibility with management objectives. In this paper we address the origins, and development of grass cultivars that have been used on national forests and grasslands in the Pacific Northwest. The genetic and ecological consequences of their use are discussed as well as recommendations for selection of plant materials for restoration projects.

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Introduction

The selection of revegetation material is a key step in restoration projects. One ready source of grass seed can be found in grass cultivars, which are seed sources for individual species that have been selected for particular traits. Cultivars are given brand names that usually provide little clue to their origin, development, or even their species. It is the responsibility of all project managers to know the source of the seed they select to sow and to evaluate the impact that this seeding will have on the success of the project and on the native plant community.

What are cultivars?

The term "cultivar" derives from a combination of the words "cultivated variety." A cultivar is a distinct, intentionally developed subset of a species that will behave uniformly and predictably when grown in an environment to which it is adapted. Anyone may develop cultivars. Seed companies, plant breeders, universities, non-profit organizations, and a variety of government agencies all are involved in cultivar research and development.

Grass cultivars have been used in large quantities, often without an assessment of the consequences.

It is important to address grass cultivars because they have been used in large quantities, often without an assessment of the consequences. Expediency can lead a project manager to buy seed "off the shelf" rather than to collect native local seed; however, use of such material may have long-term and possibly irreversible genetic and ecological effects. It is essential to have a thorough understanding of plant material genetic origins, biological attributes, and level of compatibility with management objectives before using grass cultivars.

This report was written for restoration specialists who manage National Forest System lands in the Pacific Northwest Region (R6). Our goal is to provide tools for the evaluation of grass cultivars as potential sources of seed for revegetation projects, because informed decisions are more likely to lead to success.

Our objective is to address the following questions:

1) What are grass cultivars?
2) How are they developed?
3) How have they been used on national forests and grasslands in the Pacific Northwest?
4) What is the development and description of particular cultivars that have been seeded in the Pacific Northwest?
5) What are the genetic implications of cultivar use?
6) What factors should be considered when evaluating the potential use of cultivars for revegetation?

Terms and definitions

A number of terms describe the origin of seed. For example, the term *native seed* can be interpreted a number of ways. A ***native*** plant species is one that was present in North America prior to European arrival. However, when describing a species as native, you must reference a particular area, because the answer to the question, “Is it a native species?” will depend on the location of interest. For example, bluebunch wheatgrass is native to the United States; however, if we are focusing only on the State of Washington, this species is native to areas of eastern Washington but not native west of the Cascade Mountains. A ***local native*** is a plant species that originates in the location of interest. The geographic and elevational boundaries that define a species’ local source are determined by seed movement guidelines, which address genetic variation and adaptability. ***Non-local native*** plant material is seed or cuttings that did not originate from a local source. One example of this is bluebunch wheatgrass collected from Wyoming that might be considered for sowing in eastern Washington. Other definitions and examples developed for the Wenatchee National Forest that relate to plant origin are given in the Appendix 1.

Guide to this document

This document begins with a discussion of the origins and development of cultivars used by the Forest Service in the Pacific Northwest, followed by a section describing genetic considerations of cultivars, including their impacts and concerns, and a section on objectives, assumptions, and risks (OAR). Our list of recommendations for resource specialists concludes the text. Appendices provide definitions referring to plant origin for the Wenatchee National Forest, guidelines for certification of native plants, and detailed descriptions of each cultivar, including maps.

Origins and development of cultivars used by the Forest Service in the Pacific Northwest

Most of the cultivars of native grasses considered in this paper were developed by either the USDA Natural Resources Conservation Service (NRCS) Plant Materials Program or the USDA Agricultural Research Service (ARS). This section provides a brief discussion of the history and missions of these two plant materials programs and their roles in developing cultivars of native grasses. A generalized discussion describes the process by which a cultivar is developed.

NRCS—Plant Materials Program

The NRCS Plant Materials Program (PMP) originated in the 1930s, with the creation of nurseries to grow and distribute plants as a way to address that era's severe soil erosion problems. The work of the PMP falls under the larger mission of the NRCS (formerly the Soil Conservation Service, SCS), to provide "leadership in a partnership effort to help people conserve, maintain, and improve our natural resources and environment" (USDA NRCS 2001).

The PMP currently consists of 26 plant materials centers (PMCs) and 17 plant materials specialists distributed across the nation (NRCS no date[1]). Most of the native grass cultivars used on national forests and grasslands in the Pacific Northwest were released by the PMC located in Pullman, Washington. Others came from PMCs in Oregon, Idaho, Montana, and New Mexico.

The original emphasis of the PMP was on the long-term development of cultivars—the collection, development, and release of selected plants to be used for a range of soil and water conservation purposes. Historically, the PMP focused on conservation issues associated with agricultural soil conservation and improved grazing. The cultivars developed for these purposes originated from accessions of species both native and not native to the U.S. A collection of plant material from a particular location is called an accession and is assigned an identifying number.

Key terms

Accession ~ a collection of plant material from a particular location.

Cultivar ~ a distinct, often intentionally bred subset of a species that will behave uniformly and predictably when grown in an environment to which it is adapted. Also known as variety or release.

Germplasm ~ the total genetic variability, represented by seeds or other propagative material, available to a particular population of organisms.

Ploidy ~ the number of complete chromosome sets in the cell nucleus (such as diploid, tetraploid, etc.).

Seed increase ~ the sowing and growing out of seed from a given source for the purpose of creating a larger volume of seed.

More recently, the PMP has become involved in developing releases of native plant materials adapted to smaller geographic scales for use in ecological restoration. The program now cites stream restoration, rangeland restoration and maintenance, mine reclamation, rehabilitation after wildfires, and the reduction of invasive weed species among the purposes for the plant releases it develops.

Although a cultivar has been developed for particular uses or appears to be adapted to a wide range of conditions, the material may not necessarily be suitable or optimal for all situations.

Although a cultivar has been developed for particular uses or appears to be adapted to a wide range of conditions, the material may not necessarily be suitable or optimal for all situations.

Note the following disclaimer by NRCS regarding the use of ‘Arlington’ and ‘Elkton’ blue wildrye cultivars:

> “CAUTION: ‘Arlington’ or ‘Elkton’ are not necessarily intended to replace ‘local’ or on-site sources of native blue wildrye for ecological restoration plantings. NRCS makes no claims concerning the suitability of these selections in native plant restoration efforts. Individuals with such concerns for a particular environment or ecosystem should make their decisions on a case-by-case basis”(Darris 2001).

Plant material developed and distributed by the PMP includes seeds and growing stock of grasses and grass-like plants, legumes, forbs, shrubs, and trees. The program has released more than 500 plant cultivars since its inception (NRCS no date [2]). The bulk of these releases—292 through September 2002—are grasses (Davis, Englert, and Kujawski 2002).

ARS—Western Regional Plant Introduction Station

USDA’s Agricultural Research Service (ARS) also is active in developing cultivars. According to its mission statement, the ARS

> “…conducts research to develop and transfer solutions to agricultural problems of high national priority and provides information access and dissemination to: ensure high-quality, safe food and other agricultural products; assess the nutritional needs of Americans; sustain a competitive agricultural economy; enhance the natural resource base and the environment; and provide economic opportunities for rural citizens, communities, and society as a whole” (USDA ARS 1999).

Compared to the NRCS Plant Materials Program, the ARS is focused more on agricultural issues than on natural resource issues.

In the context of cultivar development, one of the more interesting aspects of ARS’ work is the National Plant Germplasm System, whose mission is to collect, store, and maintain plant germplasm—seeds and clonal material—for use in research. The agency has four regional plant introduction stations for this purpose, as well as a central germplasm storage facility in Logan, UT. Many of the 30 grass cultivars discussed in this paper have their origins in germplasm accessions stored at the ARS Western Regional Plant Introduction Station (WRPIS), established in 1952 and located in Pullman, WA.

The initial purpose of WRPIS was to acquire new germplasm and establish a germplasm maintenance program. Subsequent developments in the plant sciences served to broaden the station’s activities. WRPIS’ current mission is “to acquire, maintain, evaluate, document, and distribute” plant germplasm. The station currently maintains germplasm from more than 2,600 species from 376 genera. It also continues to acquire new plant materials from ongoing collection expeditions in the U.S. and abroad, and from donations from other collectors (WRPIS no date).

The WRPIS maintains its library of germplasm through controlled storage (temperature and humidity) and seed increase. Its increase activities are designed to preserve the maximum genetic diversity and the integrity of the original sample. The station provides small amounts of seed (usually 250 seeds) to domestic and foreign researchers (WRPIS no date).

In the development of a cultivar, material from one or more accessions of a particular species is chosen and selectively bred to promote specific heritable traits.

One of the activities for which researchers use the germplasm stored by the WRPIS is the development of cultivars. Most of the original accessions from which the cultivars discussed in this paper were developed are stored and maintained by the WRPIS. In addition, an accession made from the final group of selected plants from which a cultivar was developed often is submitted to the WRPIS for storage and maintenance. For instance, Draylar, a cultivar of upland bluegrass (*Poa glauca* ssp. *glauca*) that was released in 1965, is stored as accession number PI 578807. Draylar itself was developed from accession number PI 109350, which was collected near Chorsum, Turkey, in 1935, and which is also stored and maintained by the WRPIS.

From source to seed: how cultivars are developed

In the development of a cultivar, material from one or more accessions of a particular species is chosen and selectively bred to promote specific heritable traits. The goal of the process is to develop a plant or population that consistently displays superiority in the selected trait(s).

Collection, selection, and testing

The process of developing a cultivar begins when the original plant material is acquired through collecting expeditions (in the U.S. or abroad) or through donors, institutions, private collectors, or other programs (such as the National Plant Germplasm System).

Material from these parent plants is "increased"—planted or sown to create a larger volume of seed. Further selections are made based on the degree to which testing reveals that an individual plant or population exhibits one or several desired traits, such as: growth rate, size, vigor, resistance to certain diseases, drought tolerance, shade tolerance, aggressiveness, winter hardiness, persistence, growth habit, leaf width, color, rate of vegetative spread, forage quality, ploidy level, seed production, seed size, rapidity of germination, uniformity of seed maturation date, and resistance to seed shattering. Testing and development of a cultivar occurs over multiple generations of intentionally selected plants and can take many years.

A cultivar may be developed from a single individual plant (such as the 'Newport' cultivar of Kentucky bluegrass); from material from a single accession (such as the 'Whitmar' cultivar of bluebunch wheatgrass); or from material from several accessions collected across a narrow or wide geographic range. Cultivars may also be developed from plants of a pre-existing cultivar, from crosses between cultivars, or from crosses between cultivars and other accessions.

Documentation and naming

Once the desired traits are well-established, documentation for the cultivar is reviewed at a national level by the USDA Plant Variety Protection office. The cultivar is given a unique trade name chosen by the breeder and is released for commercial production. These single-word names often relate to the place of origin, species name, cultivar characteristics, or an individual involved in the process. Examples are given in table 1.

Table 1. Examples of grass cultivar names and their sources

Cultivar name	Named for
'Arlington'	Source—Arlington, WA
'Bromar'	*Bromus marginatus*
'Canbar'	Canby bluegrass, now called Sandberg bluegrass
'Covar'	"Cover"
'Elkton'	Source—Elkton, OR
'Joseph'	Chief Joseph
'Luna'	Source—Los Lunas, NM
'Magnar'	Large or great
'Nezpurs'	Nez Perce Indian Tribe
'Oahe'	Source—Oahe Dam in South Dakota
'Schwendimar'	Seed collector—J. Schwendimar
'Secar'	"Seca" means dry in Spanish
'Sherman'	Source—Sherman County, OR
'Whitmar'	Source—Whitman County, WA

Certification

Once a cultivar has been developed and released, it enters the commercial market and is available for commercial growers to increase for sale. To ensure that purchasers of cultivar seed are getting what they pay for, cultivar seed must be certified by a state seed certification entity. The certification process is intended to control genetic drift and to maintain the characters and identity of the cultivar.

Four classes of certified grass seed exist in the U.S.:

- Breeder,
- Foundation,
- Registered, and
- Certified.

Breeder seed for a cultivar is maintained and distributed by the entity that developed the cultivar. Breeder seed (generation 1, or G-1) is usually the seed that is closest in

Seed certification agencies

In Washington, grass seed certification is handled by the Washington State Department of Agriculture's Seed Program. In Oregon, the certifying entity is the Oregon Seed Certification Service.

genetic makeup to the selected plants (G-0) from which the named cultivar was derived. Breeder seed generally is not found in commercial circulation but rather is supplied, usually on contract, to growers of foundation seed.

Foundation seed (G-2) is harvested from plants grown from breeder seed. The distribution of foundation seed is the point at which most cultivar production enters the commercial market.

Foundation seed is used to produce **registered seed** (G-3) or **certified seed** (G-3 or G-4). Some breeders choose to omit the registered class for various reasons, including genetic stability concerns and stock seed control issues (Doug Boze, Washington State Crop Improvement Association, personal communication, 2003). If registered class seed exists, it may be used to produce certified seed. Certified seed from different lots and growers can be blended as long as the seed lots being blended meet certification, noxious weed, and germination standards (WAC 16-302-140).

Seed produced from the certified class and beyond is called **uncertified** or **common seed**. Unless the developer of the cultivar has been granted plant variety protection for the cultivar (legal intellectual property rights protection under the Plant Variety Protection Act, administered by the USDA Plant Variety Protection Office), it is legal to market uncertified or common seed under a cultivar name. However, there is no verification that such seed actually is the cultivar as labeled.

Variety releases: manipulated track and natural track

The cultivar development processes known as “manipulated track” and “natural track” move through similar stages on the way to the development of named cultivars: selected class, tested class, and the final emergence of a named variety or cultivar. The key differences between the two processes, as outlined in fig. 1, are in the source of the original accession(s) and in the degree of manipulation this original material undergoes.

The manipulated-track process generally begins with “bulk” populations—assemblages of potentially broad composition that can contain recombinations, mass selections, and modified germplasms from multiple sources and locations, including natural populations. From this point forward, the material *within* this source is compared, selected, tested, and manipulated through multiple generations. In each ensuing stage, the initial generation (G-0) consists of intentionally selected and/or manipulated germplasm (breeding lines, clonal groups, inbreds, synthetics, and manipulated accessions).

The natural-track process begins with source-identified field collections. Each stage along the development path (fig. 1) initiates with such an unrestricted natural accession. Any comparison or selection that occurs is made *among* accessions, rather than within them. In theory, the resulting material remains genetically very close to the original germplasm.

FIGURE 1. *Germplasm development flow chart.*

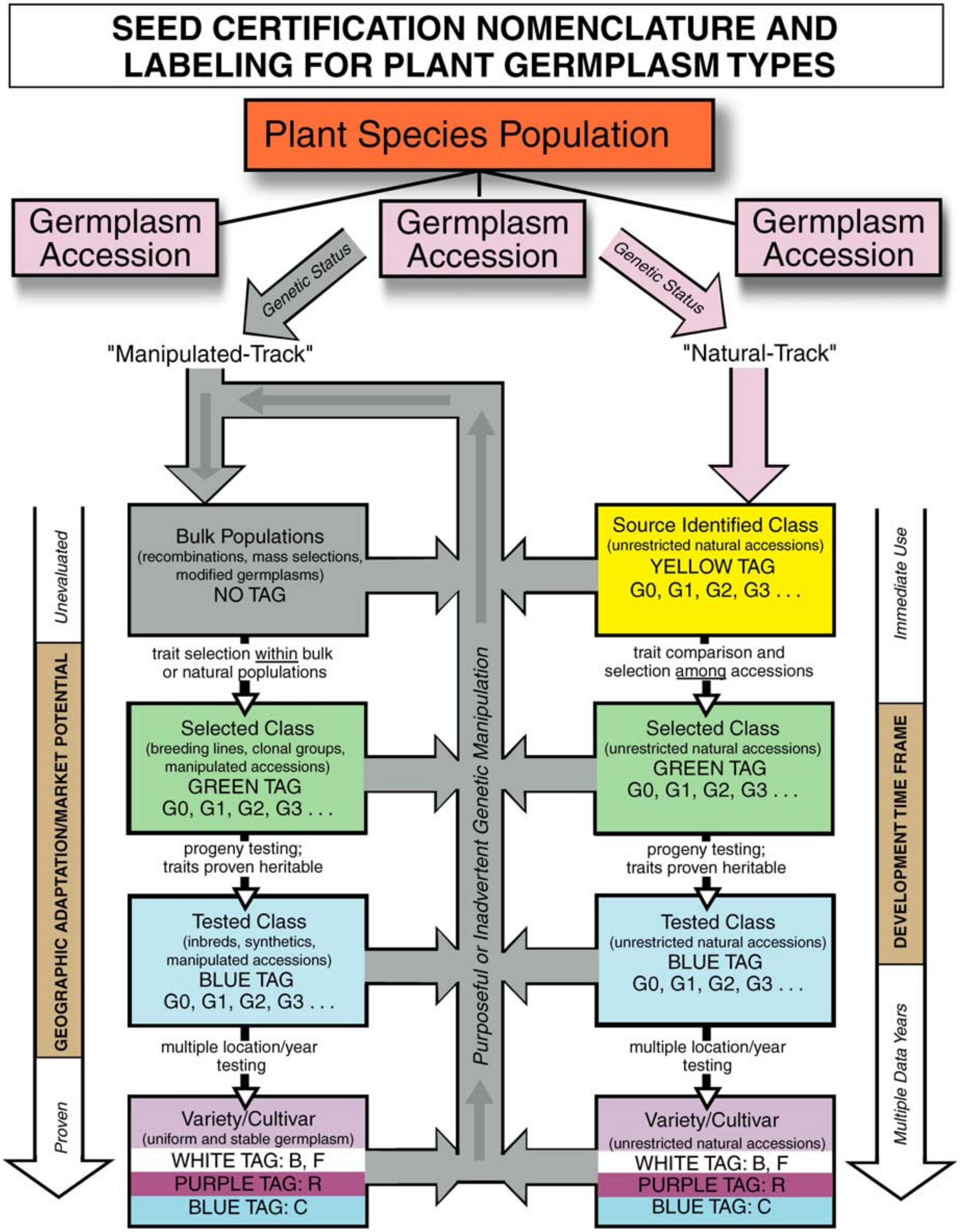

Figure 1. Germplasm development flow chart (AOSCA 2003).

Pre-varietal releases

The pre-varietal germplasm (PVG) release process, also called the "alternative release system," has been in place for tree seed certification since the 1950s. In 1994, the Association of Official Seed Certifying Agencies (AOSCA) clarified this process and expanded it to include grasses, forbs, and shrubs. AOSCA's Pre-Variety Germplasm Standards (AOSCA 1994, cited in Young 1995) provide for the certification of plant germplasms that either have not yet been developed to cultivar status or are not intended to be developed to that extent, but for which there is an immediate market need (Young 1995).

Pre-varietal releases are not full-fledged cultivars—they have not gone through the multiple-generation selection and evaluation process associated with cultivar (variety) releases. Pre-varietal releases can be made at the source-identified-class stage of the natural track process, and at the selected- and tested-class stages of either the natural track or the manipulated track process.

In an effort to maintain genetic integrity of native plant material, NRCS recently adopted the pre-varietal release concept for many of its native plant releases (Lambert 1997). For most of its native pre-varietal releases, NRCS also has tended toward the natural track of the cultivar development process. An example of a natural track, certified seed, pre-varietal release is Washoe Germplasm basin wildrye *(Leymus cinereus)*, released by the Montana PMC in 2002 (Marty 2002). The source material for this release was a collection of seed from more than 50 plants taken from a single site in Deer Lodge County, MT.

In contrast, an example of a selected-class, manipulated track pre-varietal germplasm release is 'P-7' bluebunch wheatgrass *(Pseudoroegneria spicata)*, released in 2001 by the ARS Forage and Range Research Laboratory in Logan, UT. In the development of P-7, two cultivars and 23 open-pollinated collections from Washington, Oregon, Nevada, Utah, Idaho, Montana, and British Columbia were intentionally intermated (Jones et al. 2002), a situation that would not have occurred naturally.

Source-identified class

Source-identified class pre-varietal releases originate from plant materials from a naturally growing population occurring in a known or defined geographic area. Material sold commercially may be collected directly from the site or grown under cultivated conditions. No selection or testing has been conducted, and seed grown under cultivation should be representative of the entire parent population (Pfaff, Gonter, and Maura 2002). The purpose of source-identified certification is to ensure that the material does indeed originate from the indicated location. Source-identified class material can be released for immediate use.

Selected class

Selected class pre-varietal releases consist of material from plants that (a) have been through some testing and selection and (b) show desirable superior traits or show promise of performance when compared to other accessions at a common site. However, performance of this material has not been proven through progeny testing, and it will not have been tested at multiple sites or for more than one generation. Plants may not breed true, and desirable characteristics may not show up in all offspring (Pfaff, Gonter, and Maura 2002).

Tested class

Tested class pre-varietal releases are derived from plants that have been through testing for more than one generation. This includes testing on multiple sites with replicated plots to verify performance and heritability of desirable traits. There has been some selection, and the material has proven genetic superiority or possesses distinctive traits for which heritability is stable. The complete area of adaptation may not be known (Pfaff, Gonter, and Maura 2002).

Certification of native plant material

Appendix 2 contains guidelines for certification of native plants, developed by Stanford Young of the Utah Crop Improvement Association. While these guidelines have not been officially published by the AOSCA, they do provide a summary of the germplasm development information and documentation necessary for certification of native plant materials as source-identified, selected, tested, or variety status (Young 2004).

Grass cultivars used on national forests and grasslands in the Pacific Northwest

Survey results

In 2003, the authors conducted a survey to quantify the use of grass cultivars on national forests and grasslands in Oregon and Washington. The eight forests that responded reported a total of 20 grass cultivars that have been seeded on National Forest System land from as early as 1970 to the present (table 2). More than half a million pounds of seed have been applied, and 13 cultivars are still in use. Some of these are cultivars of grasses that are native to the Pacific Northwest, while some are non-native or non-local natives (table 3). Their impact on local plant communities will vary considerably depending on their seed origin. To provide land managers with information that pertains to materials that have been or are still in use, this report focuses primarily on these 20 cultivars. Because blue wildrye is a species frequently considered for use in revegetation, ‘Arlington’ has also been included. Profiles of each grass cultivar and maps of the site of the original seed collection and the site of cultivar development can be found in appendix 3.

Table 2. Results of 2003 survey of national forests in Oregon and Washington.

Cultivar	Scientific name	Common name	# forests reporting current or past use	Years of reported past use	Cultivar currently in use	Quantity reported (total lb of seed)
'Bromar'	*Bromus marginatus*	mountain brome	2	1999–2001	No	542
'Canbar'	*Poa secunda*	Canby bluegrass	1	2001	No	16,900
'Covar'	*Festuca valesiaca*	false sheep fescue	3	1992–2002	Yes	5,550
'Critana'	*Elymus lanceolatus* ssp. *lanceolatus*	thickspike or streambank wheatgrass	1	1994	No	5,200
'Durar'	*Festuca trachyphylla*	hard fescue	3	1970, 1988, 1999–2002	Yes	66,974
'Elkton'	*Elymus glaucus* ssp. *jepsonii*	blue wildrye	2	1998–2002	Yes	500
'Goldar'	*Pseudoroegneria spicata* ssp. *spicata*	bluebunch wheatgrass	1	2002	Yes	150+
'Greenar'	*Thinopyrum intermedium*	intermediate wheatgrass	1	1970–1995	No	37,000
'Joseph'	*Festuca idahoensis*	Idaho fescue	2	1998, 2001	No	260
'Latar'	*Dactylis glomerata*	orchardgrass	5	1970–1995	Yes	115,150
'Luna'	*Thinopyrum intermedium*	pubescent wheatgrass	2	up to 1995	Yes	N/A
'Magnar'	*Leymus cinereus*	basin wildrye	1	1999	No	100
'Manchar'	*Bromus inermis*	smooth brome	2	1970–1995, 2001	Yes	2,900+
'Oahe'	*Thinopyrum intermedium*	intermediate wheatgrass	1		No	N/A
'Primar'	*Elymus trachycaulus* ssp. *trachycaulus*	slender wheatgrass	1	1994	Yes	400,400
'Schwendimar'	*Elymus lanceolatus* ssp. *lanceolatus*	thickspike wheatgrass	1		Yes	20,275
'Secar'	*Elymus wawawaiensis*	Snake River wheatgrass	1	1998–2000	No	899
'Sherman'	*Poa secunda*	Sandberg bluegrasss	2	1994–2001	Yes	4,770
'Sodar'	*Elymus lanceolatus* ssp. *lanceolatus*	streambank wheatgrass	1		Yes	N/A
'Whitmar'	*Pseudoroegneria spicata* ssp. *spicata*	beardless wheatgrass	1	2001	Yes	62,700

N/A = not applicable or not reported. Source: data on file at Olympic National Forest, Olympia, WA.

Table 3. Grass cultivar collection and release years and origins

Release name	Scientific name	Common name	Seed source collection year	Release year	Origin
'Arlington'	*Elymus glaucus* ssp. *glaucus*	blue wildrye	1979	1995	Arlington, Snohomish County, WA
'Bromar'	*Bromus marginatus*	mountain brome	1933	1946	Washington State University Campus, Pullman, WA
'Canbar'	*Poa secunda*	Sandberg bluegrass	Unknown	1979	Blue Mountains, Columbia County, WA
'Covar'	*Festuca valesiaca*	false sheep fescue	1934	1977	Konya, Turkey
'Critana'	*Elymus lanceolatus* ssp. *lanceolatus*	thickspike or streambank wheatgrass	1960	1971	Havre, MT
'Durar'	*Festuca trachyphylla*	hard fescue	Before 1934	1949	Introduced plants from Turkmenistan in old planting near Union, OR
'Elkton'	*Elymus glaucus* ssp. *jepsonii*	blue wildrye	1979	1997	Near Elkton, OR
'Goldar'	*Pseudoroegneria spicata* ssp.*spicata*	bluebunch wheatgrass	1934	1989	Malley Ridge, Umatilla National Forest, Asotin County, WA
'Greenar'	*Thinopyrum intermedium*	intermediate wheatgrass	1934	1945	Former USSR
'Joseph'	*Festuca idahoensis*	Idaho fescue	Unknown	1983	CA, ID, MT, OR, WA, WY; British Columbia, Saskatchewan, Canada
'Latar'	*Dactylis glomerata*	orchardgrass	1934	1957	Leningrad, Former USSR
'Luna'	*Thinopyrum intermedium*	pubescent wheatgrass	1934	1963	Ashkhabad, Turkmenistan
'Magnar'	*Leymus cinereus*	basin wildrye	1939	1979	Saskatchewan, Canada
'Manchar'	*Bromus inermis*	smooth brome	1935	1943	Manchuria, China
'Nezpurs'	*Festuca idahoensis*	Idaho fescue	Unknown	1983	CA, ID, MT, OR , WA, WY, British Columbia, Saskatchewan, Canada
'Oahe'	*Thinopyrum intermedium*	intermediate wheatgrass	1932	1961	Former USSR
'Primar'	*Elymus trachycaulus* ssp. *trachycaulus*	slender wheatgrass	1933	1946	Beebe, MT
'Schwendimar'	*Elymus lanceolatus* ssp. *lanceolatus*	thickspike wheatgrass	1934	1994	Near The Dalles, OR
'Secar'	*Elymus wawawaiensis*	Snake River wheatgrass	1938	1980	Snake River Gorge near Lewiston, ID
'Sherman'	*Poa secunda*	Sandberg bluegrass	1932, 1935	1945	Moro, Sherman Cty, OR
'Sodar'	*Elymus lanceolatus* ssp. *lanceolatus*	streambank wheatgrass	Unknown	1954	Canyon City, Grant County, OR
'Whitmar'	*Pseudoroegneria spicata* ssp. *Inermis*	beardless wheatgrass	Unknown	1946	Near Colton, Whitman County, WA

Sources: see Appendix 3.

Examples of cultivar development

The grass cultivars that we consider in this paper vary in their origins and development history. Several are not native to North America but were introduced from Turkey, China, or the former Soviet Union (USSR). The cultivars from native species were collected in Oregon, Washington, Idaho, or Montana. Some original collections were made as early as 1934 and one cultivar was released as recently as 1997. The source material came from one single collection in most cases, while several were the result of seed collection across several states. All these cultivars are perennial grasses; some are short-lived, some are long-lived, some are bunchgrasses, and some are sod forming. Some scientific names were changed as taxonomic relationships were updated. At least one cultivar—'Secar'—was found to be a different species from the original identification. The following discussion highlights the history of a few cultivars in more detail.

'Manchar'

'Manchar' is a smooth brome cultivar (*Bromus inermis* Leyss). This cool-season, perennial, sod-forming grass species is not native to the U.S. According to the published registration (Hein 1960), the Plant Materials Center in Aberdeen, ID, obtained smooth brome seed from Manchuria in 1935 (accession PI 109812). The exotic location is listed as the Kungchuling Experiment Station of the South Manchurian Railway. Seed was sown and grown for several generations at the PMC in Aberdeen. Mass selection was applied in uniform nurseries and stain tests. This cultivar was originally selected for high yield, strong seedling vigor, leafy hay, and good performance in alfalfa-grass mixtures. Its seeds threshed more easily than common brome. It was recommended for pasture or hay under irrigation or in areas with more than 14 inches of rain per year. The Idaho Agricultural Experiment Station and the Aberdeen PMC released this cultivar in 1943 as P-177. In 1946 it was renamed 'Manchar' (Manchuria + cultivar).

Grass cultivars vary in their origins and development history.

'Manchar' has been used in the Pacific Northwest for restoration and erosion control. However, in 2002, the PMC in Pullman, WA, conducted an environmental evaluation and concluded that in certain environments, 'Manchar' can be invasive (USDA-SCS et al. 2004). Production of breeder seed has been discontinued.

'Greenar'

Like 'Manchar'**,** 'Greenar' has its origins in a collection from Asia. In 1934, the Westover-Enlow expedition collected seed from intermediate wheatgrass in the former USSR (PI 98568). It was identified as *Agropyron intermedium* (Host.) Beauv (now *Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey). It is described as a "vigorously growing, mild sod forming, late-maturing, leafy, dark-green, broad-leaved, high-producing, disease-resistant wheatgrass" (Hein 1958). After one generation in the field in Pullman, open-pollinated selections were made (Washington, Idaho, and Oregon AES 2004). In subsequent generations, aberrant plants were removed; seeds were bulked and increased from field-testing (P-2327) by the Agronomy Department, Agricultural Experiment Station, and the PMC in Pullman, WA. Field-testing was conducted for more than 10 years both in pure stands and in combination with alfalfa in dry-land areas of Washington, Oregon, and Idaho, as well as in farm plantings. As part of these tests the plants were compared to other varieties of intermediate wheatgrass and bromegrass. When released, 'Greenar' was described as suited for both pasture and hay seeding, either alone or planted with alfalfa. First released in 1945 as P-2327, it was named 'Greenar' in 1956.

Arlington and Elkton

Two cultivars of blue wildrye (*Elymus glaucous* Buckl.), 'Arlington' and 'Elkton', were developed in the early 1990s by the Corvallis Plant Materials Center (PMC), Natural Resource Conservation Service. The original seed used in testing was collected in 1979. One source was a native stand of blue wildrye near Arlington in northwest Washington (200 feet in elevation). It was identified as the subspecies *Elymus glaucus* Buckl. ssp. *glaucous*, the common blue wildrye. The other source was a native stand near Elkton, OR (400 feet in elevation), northwest of Sutherlin in western Oregon. This is a separate subspecies, Jepson's blue wildrye, *Elymus glaucus* Buckl. ssp. *jepsonii* (Burtt-Davy) Gould. These two sources were tested for 4 years in an unreplicated study at the Corvallis PMC (Lambert and Darris 1997). No breeding or hybridization was involved; 128 blue wildrye accessions from western Washington, western Oregon, and northern California were evaluated. Replicated experiments were also conducted for another 4 years at Corvallis and the Skagit Valley Plant Center in northwestern Washington.

Both of these cultivars were selected for superior overall performance (among the top seven accessions) but also for their performance in areas near their point of origin (Darris 2001). Both displayed good plant vigor and good seed yields. 'Arlington' showed fewer disease symptoms, shorter culm height, later maturity, and weaker awns. 'Elkton' had greater stand longevity, early spring recovery, and early flowering and seed maturity. Each produced more biomass at test locations near their origins. This led the NRCS to recommend 'Arlington' for use in western Washington and 'Elkton' for western Oregon and northwestern California. However, Darris included the cautionary note that these cultivars "are not necessarily intended to replace local or on-site sources of native blue wildrye for ecological restoration plantings."

Secar

The seed used in the development of 'Secar' was collected on the Lewiston Grade along the Snake River Gorge near Lewiston, ID, in summer 1938. At the time it was identified as bluebunch wheatgrass, *Pseudoroegneria spicata.* It was first observed as a superior accession (PI 6409) among more than 500 beardless and bluebunch wheatgrass collections representing six ecotypes from the Pacific Northwest (Alderson and Sharp 1995). The breeding method used was mass selection from spaced plantings. 'Secar' was released in 1980. A comparative study of a number of populations of *Pseudoroegneria spicata* revealed one accession (PI 285272) from southeastern Washington that differed in its general appearance and heat tolerance and that formed sterile hybrids when crossed with other bluebunch wheatgrass selections (see discussion in Carlson and Barkworth 1997). Also, this particular population was an allotetraploid, 2N=28 (*Pseudoroegneria* species are either diploid or autotetraploid). After realizing that this accession resembled *Elymus* species in general but no known species of *Elymus* in particular, it was named a new species, *Elymus wawawaiensis* J. Carlson & Barkworth, Snake River Wheatgrass (Carlson and Barkworth 1997). This species has a narrow range: the valleys of the Snake River and its tributaries in Washington and northern Idaho. It can be confused with bluebunch wheatgrass but differs in having narrower, acuminate to aciculate glumes, a more imbricate spike, and glabrate basal leaf sheaths.

Questions to consider

To know what you are buying when you select a cultivar, you need to know more than the brand name and the species name. The commercial name gives no clue to the selection or testing method, and the species name does not indicate if the originating site is local to your project area. The following are questions to ask when considering a grass cultivar as a source of seed for restoration projects on National Forest System lands:

> *To know what you are buying when you select a cultivar, you need to know more than the brand name and the species name.*

- What is the location of the original source seed?
    - Is the species native to the U.S.?
    - Is the species a local native?
- Have there been changes in the cultivar's scientific name over time?
- What traits were used for selection?
- What breeding methods were used to produce breeder seed?
- What field testing methods were used to select the source for the cultivar?
- Where were field tests conducted?
- Could the cultivar hybridize with local grass populations?

An application of these questions for the cultivar 'Covar' reveals some valuable information table 4). The implications of seeding cultivars on native grass ecosystems will be discussed in the next section.

Table 4. Questions applied to 'Covar'

'Covar'	**False sheep fescue** *Festuca valesiaca* L.
What is the location of the original source seed?	Konya, Turkey, 1934.
Is the species native to the U.S.?	No.
Is the species a local native?	Not applicable.
Have there been changes in the cultivars scientific name over time?	Yes. The original collection was misidentified as F. ovina, sheep fescue. (See 'Covar' profile, appendix 3.)
What traits were used for selection?	Selected for use as a cover crop.
What breeding methods were used to produce breeder seed?	Selections made from spaced plantings in which aberrant types were eliminated.
What field testing methods were used to select source for cultivar?	Compared with 63 individual strains from 15 countries; released in 1977.
Where were field tests conducted?	Pullman and Lind, WA.
If non-native, could cultivar hybridize with local grass populations?	Possible but would be rare. Naturalization is greater threat. Almost impossible to distinguish Covar from native fescues.

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Genetic and ecosystem considerations

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong otherwise."

—Aldo Leopold

Introduction

Plant genetic composition can strongly influence the establishment success of revegetation projects, as well as the long-term performance of introduced seed and planting stock. The genetic resources of resident populations may also potentially be affected, particularly when the quantity of introduced material is large in relation to the native matrix, or when germplasm is used repeatedly over large areas and long timeframes.

Previous sections have described the broad array of plant materials available on the commercial market, ranging from highly selected cultivars to newer, natural-track releases. Because the use of this material may have long-term and possibly irreversible genetic and ecological effects, it is essential to have a thorough understanding of its genetic origins and key biological attributes. Compatibility with land management objectives is also an important consideration.

In this section we review how the genetic composition and environmental adaptations of plant material are affected by collection, selection, and propagation methods. We also discuss the desirable genetic qualities of plant materials used in revegetation of national forests and grasslands, and we highlight some of the consequences of ignoring genetic background and adaptability in the selection process.

Key terms

Cytotypes ~ plants or populations of a species having different chromosomal characteristics (e.g,. diploid and tetraploid forms of bluebunch wheatgrass).

Fitness ~ the relative ability of an individual to survive and produce offspring.

Genetic swamping ~ the homogenization or replacement of local genotypes as a result of either a numerical and/or fitness advantage of introduced plant propagules.

Inbreeding ~ mating between close relatives.

Introgression ~ spread of genes from one population or species into another as a result of hybridization.

Outbreeding (outcrossing) ~ mating between unrelated individuals.

Outbreeding depression ~ reduction in vigor or fertility (fitness) resulting from hybridization between genetically distinct individuals or populations of the same species.

Ploidy ~ the number of complete chromosome sets in the cell nucleus (such as diploid, tetraploid, etc.).

Polycross ~ population mixtures of outbreeding species

—From Hufford and Mazer 2003, Wright 1976.

The focus here is on plant taxa that are indigenous to the Pacific Northwest, to provide a context for evaluating those cultivars identified as most commonly used on Pacific Northwest Region (R6) national forests and grasslands (table 5). This information also will aid in the assessment of newer releases and other available plant material.

Table 5. Mating system and ploidy level of native grass and forb species commonly used on national forests and grasslands in the Pacific Northwest.

Species	Mating system	Ploidy range*	Chromosomes*
Achillea millefolium	Outcrossing, self-incompatible	2X, 4X (3X, 5X, 6X)	2n = 18, 36, (27, 45, 54)
Bromus carinatus	Selfing	2X, 4X (8X)	2n = 18, 36 (72)
Danthonia californica	Unknown	2X, 4X (6X)	2n = 18, 36 (48)
Danthonia spicata	Selfing	4X**	2n=36**
Deschampsia caespitosa	Outcrossing, apomictic depending on locality	2X, 4X (6X)	2n = 14, 28 (21)
Elymus elymoides	Selfing	4X**	2n=28**
Elymus glaucus	Selfing	4X	2n = 28
Festuca idahoensis	Outcrossing	4X**	2n=28**
Koeleria macrantha	Outcrossing, self-incompatible	2X, 4X	2n = 14, 28
Leymus cinereus	Outcrossing, self-imcompatible	2X, 3X, 4X	2n = 28, 42, 56
Lupinus latifolius	Mixed (can be partially self-, partially out-crossing)	2X, 4X	2n = 24, 48
Poa secunda	Selfing, outcrossing, and apomixis	Very high	2n = 63, 84, 147
Pseudoroegneria spicata	Outcrossing, self-incompatible	2X (4X)	2n = 14 (28)
Hesperostipa comata	Selfing	4X (?)	2n = 44

* Potentially rare cytotypes are shown in parentheses. ** Based on other members of this genus; specific information for this species is unknown.

Source: Ploidy data from R. Cronn, USFS PNW Station.

Shifting perspectives and needs

Early agronomic emphasis

Because of the early emphasis in the western U.S. on revegetating for soil conservation and forage production, older plant materials generally were developed with traditional agronomic methods and perspectives (Monsen and Shaw 2001, Rogers and Montalvo 2004). Introduced species, and some natives as well, were tested and selected for ease of establishment, vigor and biomass production, competitive ability, broad adaptability, forage value, and ability to withstand grazing. Also emphasized were traits that facilitated conventional and large-scale harvesting practices, such as evenness of ripening and reduced seed shattering.

Many of the older releases have the same undesirable attributes as domesticated crop varieties—including reduced diversity relative to unselected sources, intolerance of environmental extremes, and uniformity of pathogen sensitivity. Furthermore, cultivars of native species can intermate with resident sources and thereby potentially affect local gene pools adversely.

Ecosystem emphasis

In recent years, federal land management policies have shifted to emphasize the recovery of natural ecosystem structure and function. Accompanying this trend has been a growing recognition that high genetic diversity and adaptability are necessary for plants to withstand new biological and environmental stresses such as invasive weeds, uncharacteristic wildfires, and climate change. These changes have resulted in more ecologically and often more locally based approaches to plant material development.

> *Older plant materials generally were developed with traditional agronomic methods and perspectives. In recent years, policies have shifted to emphasize recovery of natural ecosystem structure and function.*

For example, over the past 10 years the Corvallis Plant Materials Center (PMC) has been emphasizing source-identified plant releases that is, local ecotypes. Corvallis and other PMCs have also been producing customized seedlots for Forest Service, National Park Service, and other cooperating agency revegetation needs. Researchers at the Forest Service Pacific Northwest Research Station (Corvallis), in conjunction with R6 national forest geneticists and PMC and ARS personnel, are making seed collections and conducting common garden studies to delineate species-specific seed transfer zones for the native grass and forb species most widely used in restoration plantings. The Forest Service Rocky Mountain Research Station (Boise, ID, and Provo, UT) also researches plant adaptations and native material development within an ecological framework.

Native seed availability

The increased demand for restoration-oriented native plant materials, along with the growing use of the natural track certification program, have greatly broadened the array of native species and geographic sources available for purchase (McArthur and Young 1999, Rogers and Montalvo 2004). Private seed companies in Oregon and Washington, such as L&H Seeds Inc. and Pacific Northwest Natives, are now marketing source-identified native germplasm for a number of species in selected ecoregions and geographic areas throughout the Pacific Northwest.

In R6, many national forests and grasslands have initiated native seed collection and propagation programs similar to those in place for conifer species. Grass and forb seed production has been conducted primarily at the J. Herbert Stone Nursery (Medford, OR). Both the Lucky Peak Nursery (Boise, ID) and Coeur d'Alene Nursery (Coeur d'Alene, ID) also now produce local native material for agency seedbanks and projects. Increasingly, Forest Service units are directly contracting with private seed growers in the Willamette Valley and Columbia Basin of eastern Washington.

In 2002, an interagency contract was awarded that provides both Forest Service and Bureau of Land Management (BLM) personnel quick and easy access to a pool of highly qualified local native seed producers. In the first year of the contract, task orders were issued for more than 25,000 pounds of seed from 35 different grass and forb species. Growers may market excess seed, thus making local native seed more widely available to other federal and state agencies, as well as to cooperators and private landowners whose lands may also be affected by wildfires and other disturbances. Prices for local native seed sources have been steadily declining as growers gain experience and knowledge; in many cases prices are now competitive or even lower than those of commercial native cultivars.

What is “genetically appropriate”?

The genetic suitability of particular plant material depends on many factors, including land management objectives, existing and potential site conditions, and the context of the surrounding landscape.

Land management objectives

Given the legal and regulatory framework guiding the management of national forests and grasslands, the re-establishment of natural processes and vegetative conditions (or some close approximation) generally will be the desired outcome for most revegetation projects. These goals promote revegetation prescriptions that result in plant communities that are structurally diverse and fully functional in all ecosystem processes, and that consist of highly adapted native species. Maintenance or restoration of natural biodiversity should receive the greatest emphasis in places of high ecological or social value and in areas containing threatened, endangered, sensitive, or “at-risk” species or habitats. Thus, revegetation with local native germplasm is a high priority in this scheme, especially within pristine or intact ecosystems, core conservation areas, and their buffers and connecting corridors.

> *Revegetation with local native germplasm is a high priority. Cultivars of non-native species that are known to be highly invasive and persistent require strong justification for use in federal wildland settings.*

Although non-native cultivars will likely continue to play a role in revegetation efforts on federal lands, their use is on the decline and should generally be limited to only highly degraded sites where there is poor potential for native plant community recovery, or to settings where they have little chance of spreading beyond the original sites of introduction (such as around buildings on administrative sites). Cultivars of non-native species that are known to be highly invasive and persistent—such as smooth brome (*Bromus inermis*), orchard grass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), and other species that have a strong potential to displace native populations and communities—require strong justification for use in federal wildland settings.

Site conditions and context

The appropriate role for cultivars of native species is more complex and requires knowledge of their genetic origins and key attributes, in addition to consideration of land management goals and revegetation objectives. Some of the criteria by which the genetic appropriateness of specific cultivars may be evaluated include the following:

- Will they be adapted to target site conditions (for example, do they have good establishment, vigor, and reproductive capabilities)?

- Do they have sufficient diversity to respond and adapt to changing climates and challenging environment conditions?
- Are they likely to cause genetic contamination and undermine local adaptations, community interactions, and function of resident native species within the ecosystem?
- Do they have the potential to become inappropriately invasive and displace desirable species or resident native populations?
- Are they likely to be a source of exotic invasive pathogens?
- Are they likely to maintain critical connections with pollinators?

Some of these questions can be addressed by evaluating not only the cultivar's geographic origins and biological characteristics but also the collection and selection methods that were used in developing the releases. Such information can be found on PMC websites and the profiles contained in this document. Additional information useful in assessing genetic suitability includes plant breeding system, seed bank persistence, and hybridization potential with local native flora.

Evaluation of impacts and risks

Assessing the potential environmental impacts and risks of particular cultivars on native populations and ecosystems can be a challenging undertaking, especially for older plant materials for which limited genetic and ecological information is available. Since 2000, the PMC requires completion of an environmental evaluation of all new plant materials planned for release (NPMM 2000, Exhibit 540-31). Rating criteria include:

1) Ability to invade natural systems where the species does not naturally occur;
2) Negative impacts on ecosystem processes such as fire occurrence regimes or hydrology;
3) Impacts on composition of plant communities;
4) Allelopathy effects;
5) Impacts on habitat for wildlife or domestic animals, including threatened and endangered species; and
6) Impacts on other land uses.

Also evaluated are the persistence and aggressiveness of the proposed plant release and the ease of control should it become invasive. This new evaluation system provides a useful tool for estimating the potential adverse environmental effects of new releases. It can also serve as a framework for evaluating older releases, even though many of the risks are difficult to quantify.

Genetic resource issues and concerns

This section discusses specific genetic issues associated with plant material selection and use on national forests and grasslands. Criteria for evaluating genetic suitability are also provided. Because a comprehensive review of genetic principles and considerations is beyond the scope of this document, we refer readers to other sources for a more in-depth perspective. These include: Meyer and Monsen (1993), Meyer and Kitchen (1995), Knapp and Rice (1994), Lippitt et al. (1994), Linhart (1995), Montalvo et al. (1997), Lesica and Allendorf (1999), Hufford and Mazer (2003), and Rogers and Montalvo (2004). We especially recommend Chapter 8 in Rogers and Montalvo (2004), which provides a thorough overview of genetic issues and guidelines related to the purchase of cultivars and other commercial plant materials for wildland revegetation.

Genetic diversity, adaptability, and performance

Importance of genetic diversity

Maintenance of genetic diversity is considered vital to the long-term survival of plant populations and is the primary mechanism by which species evolve and adapt to changing biotic and abiotic conditions (Antonovics 1984, Huenneke 1991). Examples of traits where genetic variability would be important in restoration plantings include drought tolerance, cold hardiness, timing of flowering, germination rate, disease resistance, and tolerance of heavy metals or extreme soil pH values.

Species differ in terms of their inherent variability and degree of site specificity; however, genetic diversity and local adaptation are considered especially critical in heterogeneous regions such as the Pacific Northwest. Here, environments and climates can vary greatly in space and time, and the array of pathogens and environmental stressors is broad and constantly changing. If plant material has a limited range of drought tolerance, for example, then a harsh planting site or an unusually dry growing season could result in a complete revegetation failure. Growth or reproductive problems may not become evident, however, until the occurrence of rare or extreme events (such as drought, floods, or new pathogens) many years after the original planting.

How is genetic variation measured and monitored?

Genetic variation can be measured and monitored in several ways depending on the questions that are being asked. For example, molecular markers provide a quick method for assessing the level of genetic variation within and between populations, and for detecting changes in diversity resulting from inbreeding, genetic swamping, and hybridization. Molecular markers are generally assumed to represent neutral genetic variation and thus cannot detect changes in adaptive traits such as drought tolerance or cold hardiness.

Adaptive genetic variation is best monitored by field studies that examine morphological traits under carefully controlled and uniform environmental conditions. Such experiments are referred to as common garden studies, provenance trials, or reciprocal transplant experiments. These types of studies are used to delineate seed collection and use zones, and to assess the fitness consequences of inappropriate plant material usage.

Reasons for lack of genetic variability in some cultivars

Single-site selection. Many of the older cultivar releases (and some of the newer ones as well) have a narrow genetic base, often originating from a single or very small number of geographically limited collection areas (appendix 3 in this document, and Rogers and Montalvo 2004). Such narrow sampling may capture only a small portion of the inherent variability present in a species, resulting in higher uniformity in cultivar growth, phenology, and reproductive traits.

For example, in a study of molecular variation in the bluegrass complex (Poa secunda), Larson et al. (2001) found that the ‘Sherman’ and ‘Canbar’ cultivars are composed of only one and three fixed genotypes, respectively. Much higher levels of genetic diversity were detected in the two natural bluegrass populations included in the study, indicating severe genetic erosion in the cultivars and/or the base collections originated from few genotypes.

‘Bromar’, a cultivar of mountain brome released in 1933, was also developed from a single collection site, supposedly the Washington State University campus in Pullman, WA (the origins are questionable because the species doesn't occur naturally in this area). In a recent common garden experiment, wild mountain brome accessions originating from 150 locations in eastern Oregon exhibited significant between-plant differences (Erickson, unpublished data). In contrast, plants of 'Bromar' included in the study were exceptionally uniform and extremely late maturing, and they had much greater above-ground biomass compared to the wild sources.

Although rigorous studies are lacking for most cultivars, the limited diversity of plant materials derived from single-site populations can result in poor performance in revegetation projects. The uniformity and delayed phenology of 'Bromar', for example, could be detrimental to plant establishment, seed production, and natural recruitment in many environments and growing seasons. Another example is provided by the bluebunch wheatgrass cultivars 'Goldar' and 'Whitmar', both of which were derived from single-source populations in southeastern Washington. These cultivars are considered to have insufficient drought tolerance for surviving in drier sites or geographic regions (Jones 2003), owing in part to the low genetic diversity of the original base populations.

Despite growing knowledge regarding the strong positive relationship between genetic diversity and tolerance of environmental stresses and long-term population viability, some new plant materials are still being developed from an extremely limited number of individuals and source populations. The Pullman PMC (NRCS), for example, will soon release an ecotype of blue wildrye (*Elymus glaucus)* that originates from **a single plant** on the Wenatchee National Forest (Mark Stannard, personal commmunication). The sampled population represents only a small portion of the morphological and phenological variability that is known to exist among blue wildrye geographic sources in the inland Pacific Northwest (Erickson et al. 2004). Moreover, blue wildrye is a predominantly self-pollinating species, and progeny exhibit a high degree of within-family uniformity (fig. 2). The NRCS sampling strategy will thus result in a blue wildrye release that is essentially a clonal entity with extremely limited genetic diversity and questionable adaptive potential when inserted into wildland settings. A more ecologically appropriate sampling strategy for the species would have involved at least 50 to 60 individuals from as many source locations as possible within the proposed seed use area (Erickson et al. 2004; Rogers and Montalvo 2004).

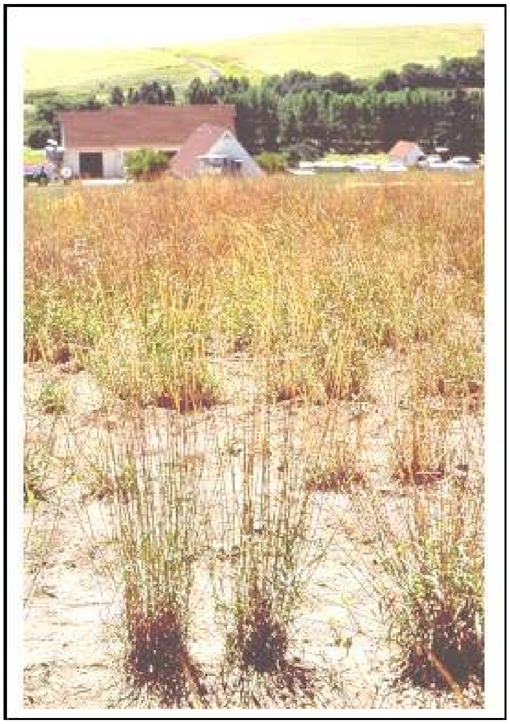

Figure 2. Blue wildrye sources from throughout eastern Oregon and Washington in a common garden study in Pullman, WA. The high degree of morphological uniformity within the two-plant family plot in the foreground was typical (Erickson et al. 2004).

Intentional trait selection. Many of the traits manipulated in traditional breeding programs—such as dormancy level, seed germination characteristics, and flowering time—are of tremendous adaptive importance in the wild (Meyer and Monsen 1993, Rogers and Montalvo 2004). If plant materials are selected for uniformity in these traits, they may fail to persist in new environments or periods of unusually early or late growing conditions.

For example, seeds of the 'Appar' flax cultivar are largely non-dormant and germinate completely in response to moisture as long as temperatures are not too high (Meyer and Monsen 1993). In contrast, unselected native sources maintain adaptive dormancy mechanisms and carry over a portion of the seedbank to germinate in subsequent years when environmental conditions may be more favorable. Similar results have been observed in comparisons of cultivars and unselected sources of needle and thread grass (*Hesperostipa comata*) and Indian rice grass (*Achnatherum hymenoides*) (Humphrey and Schupp 2002). Many other western plant species possess similar dormancy characteristics (Thompson and Grime 1979). The lack of seedbank persistence in plant materials purposefully selected for ease of harvest or establishment may greatly limit their function and sustainability in revegetation projects (Bullock 2000; Pywell et al. 2003). Recruitment difficulties caused by seedbank failure could especially be a problem in plantings that involve early seral and short-lived species (Meyer and Monsen 1993).

Some traits considered undesirable in traditional grass breeding programs—such as low seed weight and slow emergence and growth rate—may confer a selective advantage in the wild. For example, smaller seeds are found to have greater survival in the seed bank (Pywell et al. 2003, Thompson 2003). Delayed emergence would be advantageous for seeds germinating in highly variable environments or during unusually late winters. Less rapidly growing plants often have longer life spans, which is an attribute of ecological and evolutionary significance. For example, longer life spans afford greater opportunities for seedling recruitment, and in low-nitrogen environments (such as commonly occupied by native species), plants with greater tissue longevity are more efficient at retaining scarce nutrients (Aerts and van der Pehil 1993).

Unintentional selection through cultural and harvesting operations. Shifts in important adaptive traits, as well as unintentional loss of genetic variation, can also occur as a result of cultural and harvesting operations (Campbell and Sorensen 1984, Meyer and Monsen 1993, Knapp and Rice 1994). Inherent seed dormancy, for example, can be altered or even lost because of unconscious selection during pre-sowing treatments to break dormancy (Meyer and Monsen 1993, Cai and Morishima 2002). Narrow harvesting windows, although economically efficient, may miss seeds containing valuable genetic information. Important traits highly susceptible to alteration by agronomic practices include seed shattering (which aids seed dispersal); timing of flowering; and growth rate (Meyer and Monsen 1993, Knapp and Rice 1994). Rogers and Montalvo (2004) review a number of recent studies that have detected significant genetic shifts in cultivars compared to natural source populations based on evaluation of neutral molecular markers.

> *Some traits considered undesirable in traditional grass breeding programs—such as low seed weight and slow emergence and growth rate—may confer a selective advantage in the wild.*

In an effort to limit the effects of unintentional selection, the NRCS allows a maximum of four generations of seed increase for cultivars and other releases (NPMM 2000). Producing seed in agronomic environments that are similar to target revegetation sites can also help minimize changes in the genetic composition of plant material germplasm.

Risks to cultivar success from lack of genetic diversity

Regardless of the cause, the lack or loss of genetic diversity in plant material can increase the risk of inbreeding (mating among related individuals) in restored populations, especially if using single-source plant material that originates from small or isolated collection areas (Barrett and Kohn 1991; Vergeer et al. 2004). In many species, inbreeding can have detrimental effects on components of fitness, including reductions in seed production, seed weight, and the degree and rate of germination (fig. 3) (Charlesworth and Charlesworth 1987, Husband and Schemske 1996). When large areas are seeded or if the same germplasm is used continuously over time, the potential and adverse impacts of inbreeding may be exacerbated as the opportunity for gene flow or pollination from unrelated sources becomes more limited. Even species that are primarily self-pollinating may have problems, since many exhibit some level of outcrossing (Lesica and Allendorf 1999).

Hybridization potential, environmental impacts, and risks to native populations

The ability of introduced plant materials to hybridize with resident populations of the same or related species is an important consideration in restoration activities. Intermating between genetically dissimilar parents can cause poor growth and reproduction (outbreeding depression, fig. 3) in the hybrid progeny (Knapp and Rice 1994; Montalvo et al. 1997; Hufford and Mazer 2003). These effects, although not well-studied in the context of plant material introductions, may not become apparent until the second or subsequent generations after planting (Templeton 1986, Lynch 1991, Waser 1993, Hufford and Mazer 2003).

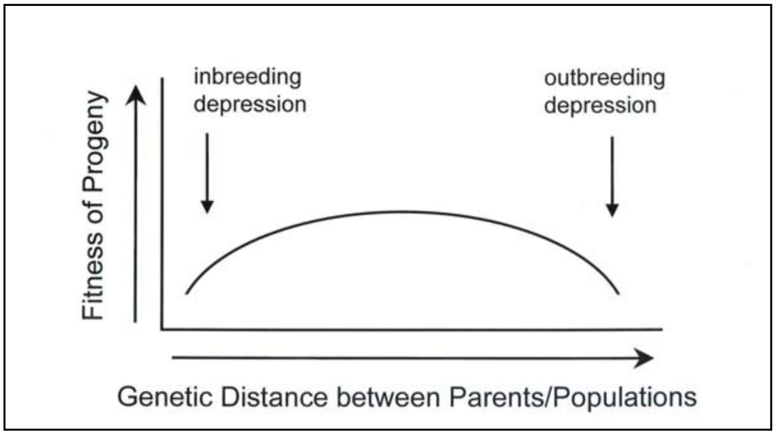

Figure 3. Predicted inbreeding and outbreeding effects in progeny as a function of the genetic distance between parental sources (after Kaye 2001).

Outbreeding depression may stem from a number of causes, each with associated impacts and risks to native populations:

- Loss of local adaptation, where the hybrid progeny are no longer well-suited to either parental environment;
- Different parental source gene combinations (coadaptations) that are disrupted in the hybrid progeny;
- Mating incompatibilities caused by differences in chromosome structure or number (ploidy) (for example, sterile progeny produced by matings between diploid and tetraploid parents).

While the particular causes and consequences of outbreeding depression are difficult to determine, careful consideration of plant material origins and attributes can help maintain the fitness and long-term sustainability of restored populations and reduce the risk of hybrid breakdown in subsequent generations. Minimizing the environmental distance that plant materials are translocated to the revegetation site, for example, can reduce the risk of high genetic divergence between introduced and local germplasm. Other factors that could be used to match plant materials to revegetation site include elevation, climate regime, soil characteristics, and pathogen pressures (Hufford and Mazer 2003).

Another way to reduce the likelihood of outbreeding depression is to avoid mixing populations from diverse geographic regions during plant material development. In an effort to create seed sources with larger potential markets, however, some researchers are promoting the development of "regional ecotypes" through the mixing of distant gene pools from a wide array of environments (Booth and Jones 2001, Burton and Burton 2002). In self-pollinating species such as bottlebrush squirreltail, mixtures of populations or lines are referred to as multiple-origin composites. Population mixtures of outbreeding species are termed polycrosses.

One recent example of a multiple origin polycross is 'P-7', which is derived from 25 accessions of bluebunch wheatgrass from six western states and British Columbia, Canada (mostly diploid, but one tetraploid source), in addition to the diploid cultivars 'Whitmar' and 'Goldar' (Larson et al. 2000). Although releases such as this polycross represent an improvement in some regards over single-source cultivars, their wide genetic variability in traits such as seed germination rate, plant size, and timing of anthesis and seed maturity, may prove difficult to maintain in commercial seed production operations. Also, because of the wide variability, many individuals may be poorly adapted to particular planting environments (that is, high variability does not necessarily equate to high adaptation). If hybridization occurs with resident populations, crosses between plants of differing ploidy levels (such as tetraploid cytotypes prevalent in the northern Rocky Mountains and diploid components of 'P-7') will have reduced fertility. The presence of hybrids with diminished reproductive capabilities may reduce effective population size and threaten the long-term viability of the restored population. Many native species used in restoration in the Pacific Northwest show considerable natural variation in ploidy level (table 5) and thus would be susceptible to mating incompatibilities with introduced plant materials of a different chromosome number.

Although problems associated with hybridization are minimized in self-pollinating species, overly broad genetic variability in multiple-origin composites could result in genetic shifts if cultivation practices or planting site conditions favor some component lines while selecting against others (Jones 2003). Because populations of self-pollinating species tend to be strongly differentiated (Hamrick et al. 1991), the geographic range of multiple-origin composites may need to be more limited than in outbreeding (or outcrossing) species (Hufford and Mazer 2003, Jones 2003).

Community interactions and cumulative effects

The introgression of genes from introduced plant material into resident populations may result in the homogenization or replacement of local genotypes, often referred to as genetic swamping (Hufford and Mazer 2003). Use of self-pollinating species can lower the threat of genetic swamping; however, moderate levels of gene movement can occur even in primarily selfing plants (Lesica and Allendorf 1999). Moreover, swamping can occur in the absence of hybridization, such as in large-scale planting projects where the introduced material has an overwhelming numerical advantage over local sources.

The type of genes and local adaptations most likely to be lost are those whose selective advantage is temporally variable or important only during extreme disturbance events or environmental conditions (Lesica and Allendorf 1999). Cold hardiness, for example, could be reduced in a population if large numbers of susceptible plant materials are introduced during a period of unusually mild climate. Genes controlling disease resistance are another type of trait that could be lost if a large introduction of nonresistant material occurs at a time when pathogen pressures are low or absent.

Of all plant material choices, single-source and highly selected cultivars that interbreed or strongly compete with local populations represent the greatest threat to genetic and ecosystem resources.

Although genetic swamping and hybridization effects of plant material introductions have been little studied, gene introgression between invasive and native species is known to have drastic consequences in native species, in some cases even leading to extinction (Levine et al. 1996, Rhymer and Simberloff 1996). Gene introgression and contamination are especially of concern in taxa whose genetic resources are already at risk, such as threatened, endangered, or sensitive plant populations.

The spread of undesirable genes from aggressive cultivars into resident populations through hybridization could potentially lead to the formation of new invasive genotypes. Although this particular consequence of plant material introductions also has not been well-studied, abundant examples show highly competitive weeds arising from gene movement from domesticated crop plants into populations of related species (Baker 1972, Barrett 1983, Ellstrand 2003, Hedge and Waines 2004). A relevant case in point is the emerging controversy over the potential for long-distance pollen movement and transfer of herbicide-resistant genes from genetically modified (GM) creeping bentgrass (*Agrostis stolonifera*) crops into resident *Agrostis* species on federally managed lands (including threatened, endangered, and sensitive taxa). Concerns over the genetic and ecological impacts of such hybridization events have led the Forest Service to officially oppose the deregulation of GM bentgrass (see proposal in the *Federal Register*, 1/5/04). This type of cryptic invasion can be greatly facilitated in species capable of extensive clonal growth, even in the absence of hybridization. Hufford and Mazer (2003) review two recent studies showing a loss in genetic diversity in native populations of common reed (*Phragmites australis*) and California cordgrass (*Spartina foliosa*) corresponding to range expansion and genetic swamping by aggressive, introduced genotypes of the same or closely related species.

There is also a risk that introduced plant material could alter successional trajectories and competitive interactions in native plant communities. Cultivars selected for aggressive traits such as vigorous vegetative growth or high fecundity can be overly competitive and directly affect intra- and interspecific plant community dynamics when introduced into natural settings (Gustafson et al. 2002, 2004; Pywell et al. 2003). For example, the overly vigorous growth of cultivars such as ‘Bromar’ may be detrimental to the establishment of mixed species restoration plantings and could also severely limit natural recruitment opportunities for other desirable species after the initial seeding (Pywell et al. 2003, Rogers and Montalvo 2004).

In addition to competitive interactions, other ecosystem properties can be altered by use of cultivars relative to local plants, including increases in photosynthetic rate (Skeel and Gibson 1996) and reductions in nitrification rates (Baer 2001). Shifts in vegetative and reproductive phenologies, flower size, and growth rate could also directly or indirectly affect important ecological functions and relationships such as natural fire processes, herbivory, and pollination and seed dispersal patterns.

Many of the cultivars used on federally managed lands have been available for more than 50 years. The cumulative effects of repeated and extensive use of a limited number of cultivars on species and community diversity and function are unknown but potentially significant. Of all plant material choices, single-source and highly selected cultivars that interbreed or strongly compete with local populations represent the greatest threat to genetic and ecosystem resources. Further harmful ecological and economic effects can occur if resource managers are unable to differentiate between introduced material and indigenous sources, such as during efforts to collect and develop local native plant materials. Native look-alikes, such as false sheep fescue (*Festuca valesiaca,* previously *ovina*) are also a concern in this context.

The cumulative effects of repeated and extensive use of a limited number of cultivars on species and community diversity and function are unknown but potentially significant.

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Selecting materials for restoration projects: objectives, assumptions and risk (OAR)

This section provides information useful for evaluating plant materials, grass cultivars in particular, for restoration projects. The key to planning a successful project is to define objectives, elucidate assumptions, and assess the risk of the various plant material options. We focus on projects that involve the use of seed used in hydro mulching or other broadcasting methods since this is the most common application of grass cultivar seed.

Objectives

A logical first step is to define goals and objectives. Knowing what must be accomplished will lead to the choice of seed that will achieve that end. We focus here on objectives, thinking of them as both short- and long-term. Objectives answer the question, "What is it we are trying to do?"

Key terms

Objectives ~ short-term desired outcomes of plans. ("Goals" are generally thought to be more long term.)

Assumption ~ a belief or logical construct underlying a plan or decision. Assumptions often are implicit (left unsaid).

Risk ~ a measure of uncertainty. In the business process, the uncertainty is about the achievement of organizational objectives. May involve positive or negative consequences, although most positive risks are known as opportunities and negative risks are called simply risks. (For risk definitions, see McNamee 1999.)

Some possible objectives for revegetation projects might include:

- Preserve and restore the natural plant community.
- Restore the site's original natural processes.
- Reestablish native vegetation that is adapted to local conditions (see Withrow-Robinson and Johnson 2004 for an excellent discussion of this topic).
- Establish grass cover to reduce the risk of soil erosion.
- Make it "green" (that is, any grass seed that germinates will do).
- Prevent exotic plant establishment or provide competition to noxious weeds.
- Keep project costs as low as possible by using the least expensive seed available.
- Complete project on time (may involve getting any seed that is commercially available).
- Keep the project simple by leaving the choice of seed mix to the contractor.

One or more objectives may apply to a particular project, and obviously some of these objectives contradict each other even though they could apply to the same project. Despite the importance of consciously articulating the project objectives, managers often are rushed, and the only objective that is served is to get seed immediately. For example, in most cases it is not possible to use local native seed without planning in advance to allow time for foundation seed collection and increase. However, running out of time or the lack of planning will limit the objectives that can be met with seeding—especially long term objectives.

Assumptions

We all make assumptions when making any decision. Assumptions often are left unsaid or may even be unconscious. As with objectives, it is important to acknowledge assumptions because they will affect the potential for a successful outcome. A few possible assumptions we might make during implementation of a seeding project might include:

- Local native seed sources are always 'best'.
- If a seed product has a brand name, it will work no matter what the grass species or its source.
- No seeding is necessary because native plants will seed in naturally.
- Seed of plant species native to the project area will work no matter what the source (non local natives).
- Seed of plant species native to the project area will work no matter how much the soil has been altered or degraded.
- All grass cultivars will work anywhere because they were developed by the plant breeders at NRCS (who are magicians, know all site conditions, and have developed cultivars to work everywhere).
- Only one seeding is needed to achieve acceptable cover.
- If seed is inexpensive, it will meet project objectives.
- If seed is easy to purchase, it will meet project objectives.
- The seed we have chosen will persist only as long as we want it to.
- The seed we have chosen will not spread outside the project area.

Assessing risk

Risk is the uncertainty about whether project objectives will be met. The issue can be framed as a two-part question: given the choice of particular plant materials, what are the possible consequences of their use, and how acceptable is the probability that these consequences will occur?

The key to successful restoration is to clearly formulate objectives, articulate assumptions, evaluate the risks, and monitor the results.

For example, suppose we select a non-native grass cultivar for seeding. If the project objectives include the preservation and restoration of the natural plant community, there is a risk of failure because the non-native grass cultivar *may* displace native vegetation and consequently reduce the diversity of plant and animal life in the watershed.

The *level* of risk will depend on the site conditions and the type of grass selected. Risk often arises when the available plant material is less than ideal. If the preferred seed is unavailable because of lack of time or funding, the project manager may have to choose among a number of less desirable alternatives. Then it becomes imperative to assess the relative positive and negative effect of each alternative.

Summary

The key to successful restoration is to clearly formulate objectives, articulate assumptions, evaluate the risks, and monitor the results. Although these significant steps are sometimes seen as a luxury (Hubbard 2000), it is imperative to integrate them into a restoration plan from the very beginning. Intentional, conscious consideration of what is being proposed, and why, will lead to thoughtful, informed decisions.

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Recommendations for resource specialists

Historically, plant materials generally have been chosen for their ability to establish rapidly and provide abundant forage and ground cover for soil stabilization. Contemporary revegetation projects on federal lands require resource specialists to broaden their expectations of plant materials to achieve not only these short-term objectives but also more long-term goals aimed at the recovery of inherent ecosystem properties—including the restoration of genetic and species diversity and natural vegetation structure and successional patterns.

To facilitate the attainment of more ecologically oriented revegetation strategies, we offer the following recommendations and considerations for plant material usage on national forests and grasslands in the Pacific Northwest:

- Native plant materials should be the first choice in revegetation projects where timely natural regeneration of the native plant community is unlikely to occur. Non-native, non-invasive plant species are appropriate for use in emergency situations to protect basic resource values, or as an interim measure when native plant materials are not available. Under no circumstances should non-native invasive plant species be used.
- Local adapted and genetically diverse native materials provide the best option for restoring functional, durable ecosystems that can withstand the multiple threats imposed by invasive weeds, uncharacteristic wildfires, and potential climate change.
- Revegetating with local native plant materials is of highest priority in natural areas of high social or ecological value, such as designated or proposed wilderness areas, research natural areas (RNAs), special interest areas, threatened and endangered species (TES) habitat or corridors, and riparian or wetland habitats.
- Road rights-of-way and trail systems should be viewed as important dispersal corridors for desirable propagules and thus worthy of revegetation with high-quality native stock.
- National forests and grasslands should continue efforts to develop reliable, stable, and economical supplies of native plant materials. These supplies are best met through collection of wildland seed sources and establishment of seedbanks for future planned projects and contingency needs. When large quantities of material are required, seed increase of wildland collections can be conducted at federal nurseries or plant material centers, or by contracting with private growers. Table 6 provides guidelines for minimizing the loss of genetic variation and unintended genetic shifts in native plant material collections and seed increase activities.
- Be an informed consumer: always use the best available information to choose genetically appropriate native plant materials for the site and situation. Commercially available plant materials should be evaluated against the criteria and guidelines provide in table 6.
- Plant materials that lack or have uncertain information about their origin and cultivation history should be avoided. Problems associated with maladaptation are likely to be reduced by selecting materials that originate from source populations in close proximity to, and with habitat conditions similar to, those of the revegetation site.
- Single-source cultivars should be avoided, especially those of outcrossing species or releases selected for high fecundity. Plant materials developed from multiple sources within a reasonably defined region are preferable and likely to show greater long-term stability and

performance. These include source-identified germplasm collected from a large number of unrelated individuals, or natural track releases originating from sites ecologically similar to the revegetation project.

- Use of highly manipulated, competitive cultivars should be restricted to only small or very highly disturbed sites in order to limit geographic distribution and potential adverse affects (fig. 4). Low cultivar diversity may affect performance, such as on sites where competition from invasive species is high. Self-pollinating species, sterile hybrid grasses, or plant releases with known low reproductive output are preferred over outcrossing or highly fecund materials.
- As the size and degree of disturbance increases, higher levels of inter- and intraspecific diversity become more important (fig. 4). In large or highly disturbed sites, for example, a mix of genetically variable genotypes of several large populations may be the most successful revegetation strategy. Mixing too broadly over geographic areas or ecological habitats, however, may result in a large proportion of individuals that are poorly adapted to the plant environment (high genetic load). As an alternative, consider the use of non-persistent, non-native grasses (for example, temporary plant cover or nurse crop).
- Develop a system for documenting, mapping, and monitoring seeding locations. Ideally, monitoring is conducted over a period of time (that is, multiple generations) so that the long-term performance and sustainability of plant materials can be evaluated.
- During seed harvesting activities, avoid sites where commercial native sources (or look-alikes such as sheep fescue, *Festuca ovina*) have been seeded.
- The revegetation potential of many native species has not been fully explored. Provide training opportunities and technical information to agency personnel on the use of native plant materials. Conduct experimental seeding trials to better determine the combinations of species and seeding rates that will best achieve short- and long-term revegetation objectives under a variety of site conditions.

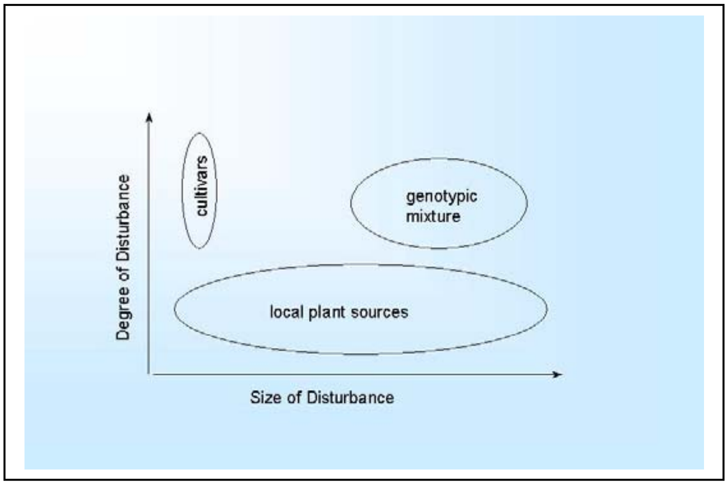

Figure 4. Relationship between size and degree of disturbance and possible sources of plant material for revegetation (after Lesica and Allendorf 1999).

- The use of highly specific native ecotypes requires a more intensive and longer term research effort compared to the planting of general purpose plant materials selected to be broadly adapted to a variety of habitat conditions. Promote research and administrative studies to better understand the appropriate spatial scale of seed transfer and of mixing populations for local native plant material development.

Table 6. Example of procedures that could minimize loss of genetic variation and unintended genetic shifts in native plant collections and releases

Activity	Procedure	Comments
Seed collection	Many individual plants per population collected (> 200) is preferred. To capture diversity of sampled population, vegetative samples require higher sample numbers than when multiple seeds are collected from individuals. Larger sample numbers are needed from inbred than outbred species.	~200 samples are needed to maintain allelic frequencies similar to the original population (Marshall & Brown 1975). About 30–60 are required to capture an average of 95% of the variation in outbred population.
	Seeds or other propagules from each individual plant should be collected and maintained separately if for container stock, plantation, or genetic studies. Bulk-collect for seed increase or direct seeding.	Family identity of seeds is valuable for genetic studies. Different mothers can always be bulked later.
	Collect seed or vegetative samples from randomly individuals using a minimum spacing criterion. Systematically sample across the population. Avoid plants with smut or obvious disease.	Stratified random sampling captures spatial variation created by limited dispersal.
	For herbaceous plants set minimum spacing of samples according to size, density, continuity of populations, and biology of species sampled. Use larger spacing for larger, low density plants or spreading clones (~ 65–325 ft) than for very small, non-clonal, high density plants (minimum of ~ 30–65 ft). For trees and shrubs, the Seed Handbook (USDA Forest Service 1993) requires minimum of 200 ft between samples.	If stands are patchy and discontinuous, collect from multiple stands in the same area within 500 ft elevational band.
	Collect seeds on enough dates to avoid selection against either early or late maturing genotypes.	Match the collecting to the distribution of maturation.
Seed increase–1st generation	Sufficient stratification, scarification, smoke, heat, or other treatment to break dormancy of all or most seeds.	Seed dormancy is an important adaptive trait.
	Establish plants from an equal number of seeds from each plant collected.	
	Grow the plants so as to minimize inter-plant competition.	
Number of generations	Few (no more than 1 is preferable).	
Seed increase location	The location should be environmentally similar to the original collection site.	This is more critical as the number of generations increases.
Harvest practices	Harvest seed in a way that captures the distribution of maturation and flowering times represented in the population. This may require more than one collection date. Develop harvest methods that capture seeds that shatter rather than selecting against seed shatter.	For seeds that shatter or fruits that have ballistic release of seeds, develop collection technique that minimizes selection of non-shattering forms (e.g., Burton and Burton 2002).

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Glossary

Accession	A collection of plant material from a particular location. An accession is assigned an identification number, which usually is preceded by the abbreviation PI (plant identification). NRCS assigns 7-digit numbers starting with ‘9’.
Adaptation	In the evolutionary sense, some heritable feature of an individual's phenotype that improves its chances of survival and reproduction in the existing environment.
Area of adaptation	The geographic range in which a given population will thrive, generally described in terms of elevation, temperature range, annual precipitation, and other environmental parameters, as well as in geographic terms.
Breeder seed	The stock seed produced by the breeder or institution that developed and maintains the cultivar. Used to produce foundation seed. Not normally found in commercial channels; the originator or owner of the variety determines the procedure for producing breeder seed and controls breeder seed distribution.
Certification	Process intended to maintain the genetic and mechanical purity and identity of commercially produced seed through all steps of production, harvesting, storage, and conditioning. The certification system involves a limited generation or pedigree system comprising four classes of seed: breeder, foundation, registered, and certified. Each class, except for breeder seed, must meet minimum established standards.
Certified seed	The progeny of foundation or registered seed, thus two or three generations removed from breeder seed. Certified seed can be used to produce only common or uncertified seed; it cannot be used to produce any other class of certified seed.
Cline	A gradual morphological or physiological change in a group of related organisms across their range, usually associated with environmental or geographic transition.
Collection	The process of locating, identifying, and harvesting generally small quantities of plant material.
Common garden study	A scientific study in which many families of a given plant species sampled from an identified geographic area are grown in a common environment. Common garden studies generally include replications in two or more growing environments. Environmentally induced phenotypic differences between the plants are minimized, allowing observation and comparison of genetically adapted traits. Common garden studies are used to determine seed transfer zones.
Common (uncertified) seed	Commercially produced seed that is fourth generation or further removed from cultivar breeder seed. This seed may be given a variety name even though it has not been certified.
Cultivar	A distinct, often intentionally bred subset of a species that will behave uniformly and predictably when grown in an environment to which it is adapted. Also known as variety or release.

Ecotype	A subset of a species that has adapted to a specific geographic environment and as a result has evolved to be genetically distinct from other members of the same species found in different environments.
Fitness	The relative ability of an individual to survive and produce offspring.
Foundation seed	The earliest (or highest) certified generation of seed available to producers for cultivar seed production. Breeder seed is planted to produce foundation seed, making foundation seed the first-generation progeny.
Genetics	The term coined by Bateson (1907) for the science of heredity and variation. The study of the patterns of inheritance of specific traits.
Genetic swamping	The homogenization or replacement of local genotypes as a result of either a numerical and/or fitness advantage of introduced plant propagules.
Genotype	The sum total of the genetic information contained in an organism.
Germplasm	The genetic material that forms the physical basis of heredity and is transmitted from one generation to the next by means of the germ cells. Often synonymous with genetic material. When applied to plants it is the name given to seed or other material from which plants are propagated.
Inbreeding	Mating between close relatives.
Increase	The sowing and growing out of seed from a given source for the purpose of creating a larger volume of seed.
Introduced	Refers to a species brought into a geographical area where it does not naturally occur. In terms of cultivars, refers to releases that were originally collected outside the USA or that were collected within the USA from plant materials purposefully introduced and maintained as an introduced population.
Introgression	Spread of genes from one population or species into another as a result of hybridization.
Local native	Refers to plants that originate in a particular locale and are adapted to specific local conditions.
Native	A plant that occurs naturally in a particular region, state, ecosystem, or habitat without direct or indirect human activity. For cultivars, native refers to releases that were collected from within the USA and that occur naturally in the USA. The definition of native can vary.
Naturalized	A plant or species known to have originated from outside a particular region, state, ecosystem, or habitat but that currently exists in the wild in that area as a self-perpetuating population because of direct or indirect human action. For cultivars, naturalized refers to releases that were present in the U.S. prior to European arrival.
Non-local native	Plant material of a native species that does not originate from genetically local sources.
Non-native	Used to describe species that do not occur naturally in a given geographic area. The term is similar in meaning to introduced.
Outbreeding	Mating between unrelated individuals.

Outbreeding depression	Reduction in vigor or fertility (fitness) resulting from hybridization between genetically distinct individuals or populations of the same species. Often not detected until the 2nd or subsequent generation after hybridization.
Plant materials	Any part of a plant collected and used to propagate the plant. Examples of plant materials include seeds, seedlings, rootstock, branches, and bulbs.
Phenotype	The observable characteristics of an individual, resulting from the interaction between the genotype and the environment in which development occurs.
Ploidy	The number of complete chromosome sets in the cell nucleus (such as diploid, tetraploid, etc.).
Polycross	Population mixtures of outbreeding species.
Pre-varietal releases	Releases that have not gone through the multiple-generation selection and evaluation process associated with cultivar (variety) releases. There has been less genetic manipulation (selection), so released materials more closely match the original source population. Pre-varietal plant materials can be released more quickly, and fewer (if any) generations occur beyond the original collection site. Pre-varietal germplasms are developed by universities, the USDA Agricultural Research Service, and the NRCS Plant Materials Center. Source-identified, selected, and tested releases are pre-varietal releases. The pre-varietal germplasm (PVG) release concept (also called the "alternative release system") was developed recently by the NRCS Plant Materials Program to address the growing demand for native plant materials and the need to introduce new plant materials more quickly to the commercial market.
Population	A group of organisms of the same species relatively isolated from other groups of the same species. A locally interbreeding population.
Registered seed	The progeny of foundation seed that is so handled as to maintain satisfactory genetic identity and purity and that has been approved and certified by the certifying agency. This class of seed should be of a quality suitable for production of certified seed.
Released Variety or "Release"	A new variety of proven value that is made available to the public, according to Experiment Station Committee on Organization and Policy (ESCOP) standards, for a conservation purpose. A term used to refer to named plant material that has been intentionally developed for commercial distribution and has gone through some level of testing. A grass cultivar is an example of a release. Although a release is not necessarily a cultivar or a variety, the terms often are used synonymously.
Seed Increase	The sowing and growing out of seed from a given source for the purpose of creating a larger volume of seed.
Seed movement guidelines	Protect the integrity of the natural pattern of adaptive variation of wild populations by restricting seed transfer to areas within which seed can be moved about freely with the expectation that they will grow and reproduce successfully and will produce no adverse genecological effects.

Seed transfer zone	The geographic region within which plant material can be moved without jeopardizing the plant's ability to thrive. The area within which a plant is evolutionarily adapted. Also the area within which transfer of material of a given species will not jeopardize the genetic integrity of other local populations of the same species. Seed transfer zones are likely to be different for species and for populations within species. Common garden studies are one method to determine appropriate seed transfer zones.
Selected release	Material from plants that have been through some testing and selection and that show desirable superior traits or show promise of performance when compared to other accessions from a common site. Performance of this material has not yet been proven because it has not yet been tested at multiple sites or for more that one generation. Plants may not breed true, and desirable characteristics may not show up in all offspring.
Selection	Natural or artificial process that results or tends to result in the survival and propagation of some individuals or organisms but not of others, with the result that the inherited traits of the survivors are perpetuated. In breeding, the directed procedure of picking certain seeds or animals for reproduction in order to influence the traits inherited by the next generation.
Selfing	Self-fertilization of an organism. In plants, selfing refers to the transfer of pollen from the anther of a flower to the stigma of the same flower or different flowers on the same plant.
Source-identified release	Plant material from a naturally growing population occupying a known or defined geographic area. Material sold commercially may be collected directly from the site or grown under cultivated conditions. No selection or testing has been conducted and seed grown under cultivation should be representative of the entire population.
Species	A group of organisms that is capable of interbreeding to produce fertile offspring. However, this biological test of a species is not always available, so there is also a morphological species concept based on anatomical similarities.
Tested release	Material from plants that have been through testing for more than one generation, including testing on multiple sites with replicated plots to verify performance and heritability of desirable traits. There has been some selection, and the material has proven genetic superiority or possesses distinctive traits for which heritability is stable. Complete area of adaptation may not be known.
Trait	An attribute or character of an individual within a species for which heritable differences can be defined.
Variation	Differences in the frequency of genes and traits among individual organisms within a population.

Variety	(1a) The botanical nomenclature division consisting of more or less recognizable entities within species that are not genetically isolated from each other, below the level of subspecies, and is indicated by the abbreviation "var." in the scientific name ("botanical variety"). (1b) The rank of taxa below subspecies but above forma; a plant that retains most of the characteristics of the species but differs in some way such as flower or leaf color, size of mature plant, etc. A variety is added to the specific binomial and preceded by "var." (such as *saxatilis* in the epithet *Juniperus communis* var. *saxatilis*). (2) Term used in some national and international legislation to denominate one clearly distinguishable taxon from another; equivalent to "cultivar." (Note: the USDA NRCS Plant Materials Program does not recognize the terms "variety" and "cultivar" as equivalent. See Cultivar.)

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Appendix 1

Definitions referring to plant origin for the Wenatchee National Forest

Definitions referring to plant origin for the Wenatchee National Forest

Native: Plant species present on the Wenatchee National Forest prior to European arrival, circa 1800.

Example: silky lupine (*Lupinus sericeus*).

Local Native: A population of a native plant species which originated, i.e., grew from seeds or cuttings, from genetically local sources. The geographic and elevational boundaries that define a species' genetically local source are determined by plant movement guidelines.

Example: Douglas-fir (*Pseudotuga menziesii*) seedlings grown from seed collected in the local seed zone.

Non-local Native: This term has two meanings: 1) a population of a native plant species which does not occur naturally in the plant community in which is it planted or 2) plant material of a native species that does not originate from genetically local sources. Non-local native plants can have detrimental effects on the composition of plant communities, plant-animal relationships, the local gene pool, and increase the risk of mortality and maladaptation.

Example:
1) black cottonwood (*Populus trichocarpa*) planted on an alpine ridge.
2) Douglas-fir (*Pseudotsuga menziesii*) seedlings originating from west of the Cascades planted on the Wenatchee National Forest.

Desirable Non-Native: Annual or short-lived perennial that is not persistent or competitive with native vegetation. Used to decrease surface erosion or as noxious weed competitors.

Example: annual rye (*Lolium perenne spp. multiflorum).*

Naturalized species: Non-native species introduced by humans to eastern Washington and have become a part of native plant communities.

Example: cheatgrass (*Bromus tectonum*).

Exotic species: Non-native species that do not occur in eastern Washington except in landscape plantings or botanical gardens.

Example: southern magnolia (*Magnolia grandiflora*).

Undesirable Plant Species: Either one of the following:

1) Plant species on the Washington Department of Agriculture noxious weed list.

Example: Dalmatian toadflax (*Linaria dalmatica ssp. dalmatica*).

2) Horticultural varieties of native species.

Appendix 2

Guidelines for certification of native plants,

developed by Stanford Young of the Utah Crop Improvement Association

Guidelines for certification of native plants

Developed by Stanford Young, Utah Crop Improvement Association

Presented at the Intermountain Native Plant Summit III, Idaho Native Plant Society, Boise, ID, November 2004

Table 2-1. Summary of germplasm development information to be considered in AOSCA germplasm category assignment

	Source identification	Selected	Tested	Variety
Germplasm identification term	Optional	Recommended	Recommended	Official name required
Geographic origin	Required	[*1]	[*1]	[*1]
Germplasm identity	Required [*2]	Required [*1,*2]	Required [*1,*2]	Required [*1,*2]
Breeding history	N/A	Required	Required	Required
Morphological traits	N/A	Document basis for selection	Prove heritability across 1 gen. [*3]	Prove heritability across 1 gen. [*3]
Performance traits	N/A	Document basis for selection	Prove heritability across (1) gen. [*3]	Prove heritability across 1 gen. [*3]
Locations/years for trait comparison or heritability	N/A	1 loc./1 year (common garden)[*4]	1 loc./1 year (common garden)	1 year at 2 or more loc. or 2 yrs at 1 loc.
Isolation during Testing	N/A	See guidelines [*5]	See guidelines [*5]	See guidelines[*5]
Data statistical significance	N/A	5% level [*6]	5% level	5% level

[*1] In the case of natural-track germplasm developed to any advanced AOSCA germplasm category, this is known. It may also be known for a germplasm which has undergone recurrent selection (manipulated-track) utilizing a population of known geographic origin. It may not be known for a species for which germplasm has been hybridized or selected (manipulated track) over many years and locations removed from original geographic sources. In this case the origin is more aptly described as genetic identity, and should be identified as the last formalized version of the germplasm known (variety or germplasm release, or other identified population from a formal germplasm development program).

[*2] The identity of germplasm existing on a given wildland site should be evaluated and noted on pre-variety germplasm tags as indigenous, non-indigenous, or unknown. This is an issue where previous vegetative reclamation has occurred and seed of a native species may have been planted hundreds of miles from its geographic origin. However, naturalized non-indigenous or unknown plant material may be developed as an manipulated-track entity to any advanced AOSCA germplasm category, with the SI site serving as a basis to formalize germplasm identity.

[*3] It is suggested that a G-1 population be produced from a G-0 accession as soon as possible, and then compared with the G-0 population in test plots if development to the tested or variety category is contemplated.

[*4] This refers to an natural-track germplasm, which derives from a comparison with other populations of the same species. A manipulated-track germplasm may result from individual plants being selected for certain traits from within the population on the site of origin, and thus establish eligibility (with documentation) for selected class solely on that basis.

[*5] This is normally not practical for test plots, but must be considered in seed increase plots so that inadvertent outcrossing is prevented. Consult recommended guidelines for isolation distances according to pollination mode and generation (AOSCA Crop Standards p. 283).

[*6] Selection (manipulated track germplasm) for specific traits on the site of origin (see [*4] above) does not lend itself to statistical interpretation, but data defining the percentage of individuals in the population selected should be provided.