"DRAFT COPY"

INTRODUCED FORAGE GRASSES

Competition, Biodiversity, and Plant Invasion

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TABLE OF CONTENTS

SUMMARY

Environmental and site conditions including geomorphology, slope, aspect, soil types, salinity, human impacts or management, seed sources, and existing vegetation determine how successful a plant species will be on a site. All plants (native and introduced) are most competitive or "aggressive" in those environments where they are best adapted. Competitiveness of a given species declines as the environment in which it is best adapted becomes less favorable. When taken to the extreme, the most aggressive of all plants do not even occur in areas outside their tolerance limits.

The impact of introduced grasses in the Columbia River drainage is not only highly site specific but also dependent upon the management conditions imposed. If all existing vegetation is removed prior to seeding by fire, grazing or cultural practices, the likelihood is greatly increased that a monoculture will follow. Furthermore, it is difficult to establish a monoculture without removal of existing vegetation. In general, each of the eight species or species complexes discussed in this review (bulbous bluegrass, the crested/Siberian wheatgrass and intermediate/pubescent wheatgrass complexes, Kentucky bluegrass, hard fescue, orchard grass, reed canarygrass, and tall wheatgrass) establish as monocultures only if all the competition is removed prior to their seeding and if no other well adapted species are present. In some instances, even when a monoculture originally developed, if seed sources of adapted species were subsequently available, mixtures of species have since developed. It is rare to find instances where the introduced grasses contained in this review have moved significantly into undisturbed areas or otherwise replaced existing vegetation. In most cases movement into unseeded areas occurs when the receiving site has been disturbed.

In those instances where equally well adapted native and introduced species occur, both contribute to biodiversity. Thus, biodiversity includes the variety of species or ecotypes present in an ecosystem that exhibits a variety of characteristics regardless of the origin of that genetic variation.

A multitude of situations and needs resulted in the initial and continued use of introduced grasses in the Columbia River drainage. The need for improved forage production for livestock and wildlife use, soil stabilization, and the absence of native species adapted to man-altered environments were important factors in management decisions. Today, both native and non-native grass species play important roles in providing a broad range of genetic diversity. They significantly contribute to biodiversity and provide options for ever changing land and management goals.

More important than the presence or occurrence of a randomly selected plant species (native or introduced) is the maintenance of soils and ecosystem processes. In light of the many worthy multiple use goals, it is our challenge as caretakers of the land to assure maximum contributions from existing species while protecting and maintaining both biotic and abiotic resources.

PURPOSE

This report examines the competitive ability, invasiveness, wildlife use and known effects on overall biodiversity within the Columbia Basin resulting from the historic and ongoing introduction of eight commonly seeded forage grass species or species complexes: bulbous bluegrass; crested, intermediate, and tall wheatgrasses; hard fescues; Kentucky bluegrass; orchardgrass; and reed canarygrass.

INTRODUCTION

To provide context for the discussions to follow on each of the eight forage-grass complexes, a general synopsis of the fundamental facets of biodiversity and the primary issues surrounding the use of introduced plant invasion is warranted. Although biodiversity is presently a "hot-topic" among academic and applied scientists, the "pure" and "applied" biological subdisciplines of biogeography, community ecology, population genetics, and range ecology have produced considerable literature pertinent to the umbrella "biodiversity" discussion. Much of this literature, however, addresses either general ecological principles or specific aspects of the targeted forage grasses, such as interspecific competition with native grass species, without reference to the larger issues of biological invasion or biodiversity. Because studies specific to the Columbia Basin are few in number, the remainder of this section will draw heavily from literature that describes general ecological theory, or from case studies involving the targeted forage grasses conducted in North America with priority given to those areas exhibiting similar physiography, climate, and biota in the Great Basin or Intermountain Region.

1) Competition

Competition for resources generally determines the presence, absence, or abundance of species within a plant community and their spatial arrangement (Pyke and Archer 1991). Fowler (1986) indicated there is sufficient evidence that competition regulates growth of plants in arid and semiarid communities. Competition among plants for resources often result in reductions in individual biomass with increases in the density of competitors (Harper 1977).

Recently several scientists have debated the importance of competition factors that form plant communities (Reichenberger and Pyke 1990, Tilman 1982, Roughgarden 1983, Schoener 1983, Strong 1983, Call and Roundy 1991, Roché 1994). However, current understanding of the subsequent processes of competition and stabilization is lacking. Therefore, we need a better understanding of the relationships among plants, animals, microorganisms, soil processes and climatic factors (Call and Roundy 1991).

Several researchers have studied competition between introduced and native species including: Hull and Klomp (1966), Hyder and Sneva (1963), Sneva and Hyder (1965), Rittenhouse and Sneva (1976; 1977), Douglas et al. (1960), Stannard (1994), Heady (1988), Rumple (1994), Harris (1977), Harris and Wilson (1970), Monsen and Anderson (1993), and Zamora (1994).

Reichenberger and Pyke (1991) found that root competition impacts fitness components of seedlings of *Artemisia tridentata* Nutt, *A. desertorum* (Fischer ex Link) Schultes, and *A. spicatum* (Pursh) Scribn. & Smith and *Bromus tectorum* L. They concluded that "even though the response of a single fitness component may vary among seedling species, interspecific and intraspecific competition play major roles in determining the abundance of individuals in populations within semiarid ecosystems."

2) Biodiversity

As noted by Noss (1991) and Walker (1992), the term “biodiversity” is now so vague, and generally misunderstood, that it is meaningless to many people. Fundamentally, biodiversity is the complete compositional and functional processes present in any ecological (abiotic-biotic) system. Examination of biodiversity as both an ecological and political concept can be categorized into two primary layers, as depicted in Table 1, i.e. global ecological complexity with anthropocentric and anthropomorphic values. Issues surrounding biodiversity are intricately intertwined with cultural, religious, and individual values and beliefs about the role of humans in global ecology.

Most articles, especially those in the popular media, that advocate concern over diminishing biodiversity tend to emphasize an anthropocentric, commodity-based view, detailing the many foods (e.g., Prescott-Allen and Prescott-Allen 1990) and drugs (Ehrlich and Wilson 1991) humans obtain from natural sources, rather than the less comprehensible, yet more critical global ecosystem processes that sustain all life. Varying degrees of biodiversity have been observed in ecosystems consisting of native and introduced species. Seeding of introduced species for site stabilization may ultimately promote establishment of native species.

More detailed reviews on biodiversity, landscape ecology, and the maintenance of ecological complexity, include: Council on Environmental Quality (1991, 1993), Ehrlich and Wilson (1991), Erwin (1991), Franklin (1993), Klijn and Udo de Haes (1994), Lacy (1987), Noss (1991), Soulé (1991), Thomas and Salwasser (1989), Walker (1992), Waller (1988), West (1993), and Wilson (1988, 1992).

3) Exotic Plant Invasion

The general topic of biological invasion, and introduced plant invasion specifically, has provoked much debate in recent years. Many of these arguments are fashioned around Clementsian concepts of plant communities and plant succession (Clements 1916, 1928). Some of these have been supplanted by the Gleasonian individualistic

Table 1. Primary non-human centered and human-centered layers involved in biodiversity. Adapted and modified from Ehrlich and Wilson (1991), Walker (1992), and West (1993).

Global Ecological Complexity

Ecosystem/Landscape
- Pattern
  - -Patch types and heterogeneity
  - -Collective species distributions
  - -Fragmentation
  - -Perimeter-to-area ratio
- Process
  - -Nutrient cycling
  - -Carbon storage
  - -Energy flow
  - -Soil development
  - -Soil erosion control
  - -Human disturbance rate
  - -Non-human disturbance rate

Community
- Pattern
  - -Physiognomic heterogeneity
  - -Structural heterogeneity
  - -Species heterogeneity
  - -Species endemism
  - -Biological invasions
- Process
  - -Colonization rate
  - -Extinction rate
  - -Patch dynamics
  - -Nutrient cycling rate
  - -Human disturbance rate

Population
- Pattern
  - -Relative abundance, frequency, and biomass
  - -Structure: sex and age ratios
  - -Morphological and genetic variation
  - -Karyotypic variants
- Process
  - -Recruitment
  - -Survivorship
  - -Adaptation
  - -Genetic drift
  - -Selection

Individual
- Pattern
  - -Heterozygosity
  - -Rare alleles
- Process
  - -Genetic
- Gene flow
- Mutation
- Selection
  - -Physiological
- Phenology
- Acclimation

Anthropocentric/Anthropomorphic Values

Economic
- Commodities
  - -Food Plants
- Domesticated crops
- Wild-gathered
  - -Livestock
  - -Clothing fabrics
  - -Energy sources
- **Services**
  - -Nutrient cycling
  - -Carbon storage
  - -Energy flow
  - -Soil development
  - -Soil erosion control

Moral
- Obligation to preserve life
- Obligation to not interfere with evolution or other species
- Obligation to pass on a livable and diverse planet to future generations of all species so as not to limit their opportunities and options

Aesthetic
- Need for appreciation of non-human created landscapes
- Need for appreciation of non-human life-forms
- Need for animal companionship

concept (Gleason 1917, 1926, 1939) and by the "state-and-transition" models elaborated by Westoby et al. (1989). Westoby et al. noted that plant associations do not operate as "organismal entities" through time and space, but rather as individual species populations with differing physiological tolerances and life histories. Consequently, local, regional, and global environmental dynamics all operate to shape the more accidental than determinant vegetation patterns observed at any one point along a time continuum.

Perhaps the most important concept to consider is that no specific spatial vegetation association or landscape (e.g., North America just prior to human occupation) holds any greater fixed value over any other temporal view of that same landscape. Through examination of the fossil record, we see that vegetation associations are plastic and quite dynamic. Arid regions of western North America experienced significant climatic changes with major vegetation expansions and contractions during the Holocene period, and even greater fluctuations during the inclusive Quaternary Period (Tausch et al. 1993). For example, Miller and Wigand (1994) detailed the notable expansion of Piñon-Juniper Woodlands, and the well-documented expansion of creosote bush into the Southwest is now a notorious ecological scenario. Also, as discussed by Delcourt (1987) humans have exerted substantial influences on North American vegetation structure and composition for several thousand years. Brandt and Richard (1994) found that within the Columbia Basin on the "protected" Hanford site, unintentionally introduced plants (cheatgrass and Russian thistle [*Salsola kali* L.]) have persisted and have invaded areas undisturbed by humans or livestock since 1944. Tyser and Worley (1992) reported a similar scenario within Glacier National Park.

Walker (1992) and West (1993) placed greater importance on the preservation of ecosystem processes than on the maintenance of any temporal species association or of "ecologically redundant" species. The concept of ecologically redundant species holds appeal when considering that some human activities have led to, and will yet lead to, the extinction of both species and habitats. However, the labelling of organisms as ecologically redundant (e.g., an introduced forage grass as the ecological equivalent of an indigenous grass) presupposes a level of understanding about such organisms that does not presently exist. We may not be able to remedy negative alterations to ecosystem processes enacted in ignorance. Some authors e.g., Orr 1990 have argued that humans will never have the capability to fully understand the complexity of our global ecology and therefore the concept of ecological "management" is ludicrous. While perhaps extreme, this contention highlights the need for caution when evaluating the "ecological importance" of any one organism.

Biodiversity issues concerned with the introduction of forage grasses can be grouped into two primary categories: 1) aspects about each individual grass species or species complex and 2) results from vegetation type-conversion. Although some authors e.g., Temple 1990 have simplistically treated introduced plants as inherently "evil organisms," others have viewed introduced plants as relatively benign additions (e.g., Lugo 1990, 1992). Still others (e.g., Johnson and Mayeux 1992) see introduced plants as having "increased species richness and probably diversity." As noted by Lodge (1993), the "truth" depends on the specific situation as each successful invasion results from the chance coincidence of numerous ecological factors - no one invasion model will hold universally. Accordingly, predictions about the "invasion potential" of any one species remain difficult, as conditions for successful introduction will vary significantly from site to site. Without doubt, the introduction of individual species can result in dramatic changes to local habitats, as with the introduction of *Andropogon virginicus* C. von Linné, *Paspalum conjugatum* Bergius, and *Pennisetum setaceum* (Forskål) Chiovenda into Hawaii (Vitousek et al, 1987). Such examples have prompted some authors (e.g., Coblentz 1991) to advocate as a condition of the introduction process that the introducer must demonstrate that a given plant will never adversely affect local biodiversity. No matter how appealing this theory may be, this proposal is impractical because one would need a parallel world in which to introduce any new species. No model or experimental plot could ever accommodate all possible ecological factors at any one site through time. Assessments regarding the invasive potential, and possible adverse affects on biodiversity of any given species can only be an "educated guess." Speculations for a given environment must draw from previous knowledge about competitive ability for space and resources, together with any known capability to pollute local gene-pools with deleterious alleles. Forage grasses are often viewed as "preadapted" invaders owing to a suite of traits selected for by plant scientists or agronomists, including high germination, strong seedling vigor, overall robustness, wide or specific ecological tolerance (e.g., salt, drought), and abundant seed production; however, "pre-adaptation" does not automatically impart invasion. Only with adequate scientific monitoring can knowledge beyond causal observations be acquired to estimate negative or positive influences that introduced species have had on local, regional, or global ecological complexity.

Perhaps an appropriate way to view the introduction of non-indigenous forages in relation to biodiversity is in the context of vegetation type-conversion. When attention is focused on introduced forage grasses in the landscape, a much greater portion of the debate centers around the removal of existing vegetation or reseeding areas where existing vegetation has been depleted with the concurrent seeding of introduced species rather than the invasion of introduced plants into relatively intact indigenous vegetation. When viewed realistically, type-conversion is a single-purpose strategy for the promotion of specific objectives that initially results in local ecological simplification through the promotion of monocultures often of significantly altered structure. Such structural changes may markedly alter the food sources, the numbers and species of animals or fauna requiring the food sources or thermal and visual cover, resulting from a habitat of more uniform height and spacing. Also, results of analysis conducted during eleven years by Tilman and Downing (1994) suggest that the more species-diverse Minnesota grasslands examined were more resilient after significant drought than grasslands with four or fewer total species. The maintenance of many species with varying tolerances to drought, frost, fire, herbivory, and fungal pathogens is more likely to ensure the persistence of some of the existing species on a given site than does a single genetically uniform cultivar.

Rangeland degradation, expanding desertification, and ecosystem fragmentation are interrelated issues of paramount concern among ecologists (e.g., Allen and Jackson 1992; Lord and Norton 1990; Milton et al. 1994; Saunders et al. 1991; West 1993). In arid regions, once vegetative cover is removed, insolation increases, hydrology is altered, soils erode, and functional processes are impaired. The resulting fragmented landscape is often vulnerable to an accelerated spiral toward perhaps irreversible desertification with potentially devastating ecological, social and political effects. Accordingly, land managers within arid regions, including North America, must examine each new type-conversion for the total ecological consequences and then work to restore fragmented landscapes (Hobbs and Saunders 1993). However, in many situations, planting of introduced grasses to preserve eroding soils and ecosystem processes is imperative.

For additional discussion of exotic plant invasion, habitat fragmentation, population fragmentation, and revegetation, see Call and Roundy (1991), Coblentz (1990), Johnstone (1986), Fowler (1986, 1990), Lacy (1987), Pyke and Archer (1991), Soulé (1990, 1991), Westman (1990), and Wilson and Belcher (1989).

BULBOUS BLUEGRASS

1) TAXONOMY AND ORIGIN

Although the genus *Poa* is among the most taxonomically perplexing of all grass genera, bulbous bluegrass, which is indigenous to Eurasia, is the only *Poa* in the United States that manifests corm-like basal internodes together with bulblet or bulbous spikelets. It therefore reproduces three different ways: underground bulblets as well as seed and bulblets produced from the stem (Winward 1994).

1.1) Scientific Names

Poa bulbosa C. von Linné, Sp. Pl. ed. 1:70. 1753.
Poa bulbosa C. von Linné var. *vivipara* Koeler, Descr. Gram. 189. 1802.

1.2) Other Common Names

Bulbous bluestem, bulbous meadowgrass, bulbous *Poa*

1.3) Cultivar Names

BULBOUS BLUEGRASS

2) COMMON USES

Pasture and soil erosion control

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Bulbous bluegrass was first introduced in the eastern United States from Russia in 1906. In 1915 it was accidentally introduced in alfalfa seed and spread rapidly throughout the western United States. Hull (1940) noted that it did well in the valleys and foothills of Oregon and Washington, east of the Cascade mountains and spread rapidly to roadsides, waste places, on bench lands, foothills, rocky slopes, in Idaho near Boise, Pocatello, Mayfield, and in Gem County, Idaho. Bulbous bluegrass was seeded into a cheatgrass stand in 1937 and 1938 along with crested wheatgrass (*Agropyron cristatum* [L.] Gaertner), and bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve). Only bulbous bluegrass survived. It is aggressive and invades disturbed areas and established stands of some other species. It produces an abundance of seed even in dry years and is well adapted to the granitic foothills of the Boise River drainage, Snake River plains, and northern Nevada and Utah. It grows aggressively in areas that receive favorable spring and fall precipitation and at elevations from 2,000 to 6,000 feet. It does well on dry gravely soil that is low in organic matter (Hull 1940).

Bulbous bluegrass, which was seeded in 1944 on the Raft River flat, 15 miles south of Rupert, Idaho, did not maintain a good stand and other species replaced the seeded area (Hull and Klomp 1967). Several plant-material scientists (Carlson, 1994; Gibbs, 1994; Harris, 1994; and Harrison, 1994) have found that bulbous bluegrass invades disturbed sites but soon gives way to longer-lived native perennials in eastern Oregon and Washington. They reported that it coexisted with other natives but did not dominate them. They found that bulbous bluegrass gives way to squirreltail (*Elymus elymoides* [Rsf.] Swezey), Sandberg bluegrass (*Poa secunda* Presl), and bluebunch wheatgrass. However, Winward (1994) noted at Baker, Oregon, that bulbous bluegrass persists under grazing pressure.

Winward (1994) found that bulbous bluegrass is extremely aggressive and invaded the valleys and foothills of the Curlew National Grasslands in south central Idaho. It is competitive in areas where the soil dries in July or August and receives 10 to 18 inches of annual precipitation. Thirty to forty-year-old stands of crested wheatgrass are currently being dominated with sagebrush, yellow rabbitbrush (*Chrysothamnus nauseosus [Pall.] Britt.),* and bulbous bluegrass. Sandberg bluegrass along with sagebrush and yellow rabbitbrush seems to coexist with bulbous bluegrass (Winward 1994).

Gomm (1974), after evaluating several plantings in western Montana, reported hat only very small amounts of bulbous bluegrass existed after the first or second year. Hoag (1994) reports that bulbous bluegrass is not aggressive on the Snake River Plains at Aberdeen, Idaho. Kreuger (1994) and Ogle (1994) reported the spread, competitiveness and aggressiveness of bulbous bluegrass at Baker, Oregon, and Fairfield, Idaho, respectively.

Bulbous bluegrass was seeded in plots at the following locations in Washington: Republic 1948 and 1949; Riverside 1950 and 1951; Yakima Training Center 1962. It did not persist and was replaced with other seeded and surrounding species by 1968 at Republic and Riverside (Harris 1994) and Yakima Training Center (Nissen 1994).

Bulbous bluegrass has become a widespread grass in the Columbia River drainage. It volunteers and is well adapted in the winter-rainfall zone. However, stands fluctuate from year to year. It often persists in mixtures with long-lived bunchgrasses from which it may invade nearby areas and is sometimes troublesome on croplands. It has many of the weedy characteristics of cheatgrass (SCS and PPMC files, Pullman, WA, researched in 1994).

3.2) Wildlife Usage

Mule deer have been observed to graze bulbous bluegrass during early spring and late fall in northern Utah and southern Idaho (McArthur 1994; Harrison 1994; Winward 1994).

3.3) Summary

Bulbous bluegrass is persistent, highly competitive, aggressive, easily regenerates itself and may become dominant on disturbed areas where adapted. Nevertheless, on many sites it either gives way to other species or coexists in mixed communities. Thus, on some sites it adds to instead of distracting from biodiversity.

CRESTED WHEATGRASS COMPLEX

1) TAXONOMY AND ORIGIN

According to the proposals of Dewey (1984) and Löve (1984), the genus *Agropyron* is restricted to those taxa comprised of the p genome. This disperses species previously treated in *Agropyron* into the following genera: *Australopyrum, Elymus, Elytrigia, Eremopyrum, Festucopsis, Pascopyrum, Pseudoroegneria, Thinopyrum*, and *Agropyron. Agropyron* is now comprised of from 10 to 20 taxa worldwide and is defined not by truly qualitative structural differences, but rather by the arbitrary division of continuous variation in rhizome elongation, culm width, leaf-blade width, spike width, spike rachis length, spike rachis internode lengths, spikelet number and attitude, spikelet length, spikelet floret number, glume length and width, glume awn length, lemma length and width, lemma awn length, palea length, and palea keel trichome number, together with the presence/absence of trichomes or purple pigmentation on various structures.

As accessions were gathered from throughout the indigenous Eurasian range of this complex and distributed by various governmental agricultural departments of Canada and the United States, the continued misapplication of scientific names to both unaltered original collections and modified cultivars has caused much confusion regarding the taxonomy of crested wheatgrasses now well established in North America. For example, in North America, the name *A. cristatum* Gaertner has traditionally been applied to the “Fairway-type” cultivar morphology following Beetle's (1961) treatment; however the true *A. cristatum sensu stricto*, as circumscribed originally and currently by Eurasian taxonomists include only those plants with oblongly-ovoid spikes, and ascending and pubescent spikelets. The “Fairway-type” morphology actually corresponds most closely to *A. pectiniforme* Römer *et* J.A. Schultes.

Two resolutions of this continuing taxonomic confusion surrounding the crested wheatgrass complex emerge: 1) a re-examination of all accessions housed in North America to render appropriate identifications in conformance with Eurasian treatments or 2) treat all *Agropyron sensu stricto* as a single polymorphic, panmictic species *A. cristatum sensu amplo* with the retention of all cultivar names. While seemingly radical, the latter option may ultimately prove the most biologically realistic and workable alternative. Following is a list of Latin names described for the various forms of the crested wheatgrass complex found in taxonomic treatments.

1.1) Scientific Names

Agropyron cimmericum Nevski, Tr. Sredneaz. Univ. ser. 8B, 17:56. 1934.
Agropyron cristatiforme Sarkar, Can. J. Bot. 34:333. 1956.
Agropyron cristatum (L.) Gaertner, Nov. Comm. Acad. Sci. Petrop. 14:540. 1770, *sensu amplo*.
Agropyron cristatum (C. von Linné) Gaertner ssp. *dasyanthum* (Ledebour) Á. Löve, Feddes Rept. 95(7/8):431. 1984.
Agropyron cristatum (C. von Linné) Gaertner ssp. *desertorum* (Fischer *ex* Link) Á. Löve, Feddes Rept. 95(7/8):431. 1984.
Agropyron cristatum (C. von Linné) Gaertner ssp. *fragile* (Roth) Á. Löve, Feddes Rept. 95(7/8):431. 1984.
Agropyron cristatum (C. von Linné) Gaertner ssp. *imbricatum* (Bieberstein) Á. Löve, Feddes Rept. 95(7/8):431. 1984.
Agropyron cristatum (C. von Linné) Gaertner ssp. *michnoi* (Roshevitz) Á. Löve, Feddes Rept. 95(7/8):432. 1984.
Agropyron cristatum (C. von Linné) Gaertner ssp. *mongolicum* (Keng) Á. Löve, Feddes Rept. 95(7/8):432. 1984.

Agropyron cristatum (C. von Linné) Gaertner ssp. *pectinatum* (Bieberstein) Tzvelev, Sched. Herb. Fl. URSS 18:25. 1970.
Agropyron cristatum (C. von Linné) Gaertner ssp. *tarbagataicum* (Plotnikov) Tzvelev, Nov. Sist. Vyssch. Rast. 9:58. 1972.
Agropyron dasyanthum Ledebour, Ind. Sem. Horti Dorpat. 3. 1820.
Agropyron desertorum (Fischer *ex* Link) J.A. Schultes *in* J.A. *et* J.H. Schultes, Mantissa 2:412. 1824.
Agropyron deweyii Á. Löve, Feddes Rept. 95(7/8):432. 1984.
Agropyron fragile (Roth) Candargy, Arch. Biol. Vég. (Athènes) 1:58. 1901.
Agropyron fragile (Roth) Candargy ssp. sibiricum (Willdenow) Melderis, Bot. J. Linn. Soc. 76:384. 1978.
Agropyron imbricatum Römer *et* J.A. Schultes, Syst. Veg. ed. 15, 2:757. 1817.
Agropyron michnoi Roshevitz, Izv. Glavn. Bot. Sada SSSR 28:384. 1929.
Agropyron mongolicum Keng, J. Wash. Acad. Sci. 28:305. 1938.
Agropyron pectiniforme Römer *et* J.A. Schultes, Syst. Veg. ed. 15, 2:758. 1817.
Agropyron sibericum (Willdenow) Palisot de Beauvois, Essai Agrost. 102, 146, 181. 1812.
Agropyron sibericum (Willdenow) Palisot de Beauvois var. *desertorum* (Fischer *ex* Link) Boissier, Fl. Orientalis 5:667. 1884.
Agropyron tanaiticum Nevski, Tr. Sredneaz. Univ. ser. 8B, 17:56. 1934.
Agropyron tarbagataicum Plotnikov, Tr. Omsk. Sel’sk. Inst. 20:131, 143. 1941-1946.
Elymus pectinatus (Bieberstein) Laínz, Bol. Inst. Estud. Astur., Suppl. Cienc. 15:44. 1970.

1.2) Other Common Names

Desert crested wheatgrass, desert wheatgrass, Fairway crested wheatgrass, Siberian wheatgrass, Siberian crested wheatgrass, Mongolian wheatgrass, Standard crested wheatgrass, Transbaikal wheatgrass

1.3) Cultivar Names

EPHRAIM, FAIRWAY, HYCREST, KIRK, NORDAN, PARKWAY, P-27, RUFF, SUMMIT, DOUGLAS, VAVILOV

2) COMMON USES

Pasture, hay, soil conservation practices, turf, wildlife

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Crested wheatgrass is one of the most successful of all grasses introduced into the sagebrush-grass ecosystem of the Columbia Basin. According to Hull and Klomp (1966), crested wheatgrass was the first successful species seeded in sagebrush-grass sites in southern Idaho and continues to be one of the best adapted species. It has wide adaptation, long life, drought and cold resistance, relative freedom from disease, good productivity and palatability, persistence under abuse, good competitive ability, high seed production, ease of establishment and excellent seedling vigor (Hull and Klomp 1966). Sharp (1986) noted that Standard and Fairway crested wheatgrass were first introduced around 1900 and have been of special significance and importance in range revegetation since the 1930's.

Dwyer (1986) and Asay (1994) stated that crested wheatgrass may be the single most economically and biologically important range plant in North America. This grass was introduced from Siberia where it evolved under and survived intensive grazing. No good estimate is available for the acreage seeded to crested wheatgrass in North America, but it has been used to replace bluebunch wheatgrass which is susceptible to defoliation. "Economically and ecologically astounding by most measures, crested wheatgrass produces from 3 to 20 times the grazing capacity of the so-called native plants it has replaced. It sustains heavy and long or even continual grazing, much to the surprise of most early range ecologists who predicted it would easily succumb to the pressures of grazing or to its new environment or a combination of both. Not only has it not succumbed, but crested wheatgrass has survived three of the century's worst droughts" (Dwyer, 1986).

"After 50 years I believe this plant has gained its ecological credentials and is now subject to our vegetative classification schemes. Therefore I (Don D. Dwyer) am declaring it *is* a range plant. We have decided here at Utah State University that crested wheatgrass deserves to receive its papers--at least a permanent work visa if we cannot grant it a citizenship based on naturalization" (Dwyer 1986).

Johnson (1986) provided an indepth literature review on seed and seedling relations of crested wheatgrass. A detailed analysis of competition with cheatgrass (*Bromus tectorum* L.) was used as an example. A summary of this analysis indicates that characteristics which make cheatgrass a strong competitor with seedlings of crested wheatgrass include: 1) high seed production, resulting in extremely large resident seed banks, 2) highly viable seed that exhibits rapid germination and aggressive emergence capabilities, and 3) rapid and extensive root penetration into the soil and extensive root system development. Although these characteristics specifically relate to cheatgrass, various combinations of these factors undoubtedly contribute to the success of other species competing with seedlings of crested wheatgrass. This review concluded that "early seedling root development and seedling ability to tolerate widely fluctuating moisture and temperature conditions undoubtedly contribute to the ease of establishment of crested wheatgrass" (Johnson, 1986).

Hyder and Sneva (1963) attributed the high grazing tolerance of crested wheatgrass to early root-growth activity, early accumulation of leaf tissue, and early accumulation of carbohydrate reserves in underground parts. Early researchers recognized the spread of crested wheatgrass such as Reitz et al. (1936) who recommended drilling crested wheatgrass in 4-row strips, 30-meters apart across the prevailing wind with an ordinary grain drill. They recommended the planting "not be grazed for 2 or 3 years to help young plants become established, make seed and spread." Stewart (1938) recommended drilling weedy land in strips across the prevailing wind to cover one-fifth to one-third of the total area.

Roots of crested wheatgrass move down in the soil faster than bluebunch wheatgrass and nearly as rapid as cheatgrass and remain in favorable moisture while bluebunch wheatgrass does not. These differences result in lower leaf water potential and poorer survival of bluebunch than crested wheatgrass (Harris and Wilson 1970).

Big bluegrass competed well with crested wheatgrass in tests at Burns, Oregon (Sneva and Hyder 1965). Sneva and Hyder (1965), Hyder and Sneva (1963), and Rittenhouse and Sneva (1976) showed that Sherman big bluegrass produced as much or more dry-matter yield than Nordan crested wheatgrass in most years. They reported in 1969, the year following the drought year of 1968, that big bluegrass produced more dry matter than crested wheatgrass. Douglas et al. (1960) and Sneva and Hyder (1965) reported that Sherman big bluegrass was earlier maturing and out yielded crested wheatgrass. Nevertheless, Douglas et al. (1960) found that crested wheatgrass was superior to Sherman big bluegrass in stand density.

Nordan crested wheatgrass and P-27 Siberian wheatgrass did not persist after 15 years at Lind, Washington and were replaced by over seeded species of Sherman big bluegrass and Secar bluebunch wheatgrass (Stannard 1994).

Crested wheatgrass seedings at the Vale, Oregon program and elsewhere (Asay, 1994; Hull and Klomp 1966; Blaisdell et al. 1982; Johnson 1986; USDA-ARS 1992; Harrison 1994) suggest that some seedings persist for a long time (30-45 years). Big sagebrush (*Artemisia tridentata* Nutt.) repopulated the crested wheatgrass area reaching about 15% relative cover during a 20-year period in plowed and seeded areas (Heady 1988). However, in the sprayed and seeded mixture areas (consisting of crested and bluebunch wheatgrass) sagebrush reached its pretreatment levels in nearly 10 years. Current management practices at Vale in the sprayed and seeded mixture areas have resulted in a decrease of bluebunch wheatgrass and an increase of crested wheatgrass. In the protected area, bluebunch wheatgrass and other native species either maintained themselves or increased moderately (Heady 1988; Rumple 1994).

Rumple (1994) noted over a 30-year period at the Vale project that crested wheatgrass plants were able to invade bluebunch wheatgrass stands in areas where bluebunch wheatgrass condition/vigor was low (livestock concentration areas, areas recovering from drought, etc.). He never observed crested wheatgrass plant density decreasing while associated bluebunch wheatgrass plant density increased. Some droughts have caused mortality to both crested wheatgrass and bluebunch wheatgrass and no plant recruitment was noticed. Big sagebrush and rabbitbrush were the only native species observed that would invade stands of crested wheatgrass. The severity of invasion is somewhat related to the vigor of the crested wheatgrass stand. Nomad alfalfa, if established, will persist in crested wheatgrass stands at Vale, Oregon. Sandberg bluegrass is commonly associated with stands of bluebunch wheatgrass, but not crested wheatgrass (Rumple 1994).

In 1966, Hull and Klomp examined nine 20- to 30-year old crested wheatgrass seedings in southern Idaho. Most of the early seedings consisted of Fairway and some Standard crested wheatgrass. Threetip sagebrush (*Artemisia tripartita* Pydh.) and big sagebrush reinvaded some areas depending on the initial seedbed preparation and available sagebrush seed. They reported that although sagebrush reinvaded, crested wheatgrass maintained its' stand and was not replaced by sagebrush. In contrast, bluebunch wheatgrass declined in density and was replaced by sagebrush in the sprayed and seeded areas.

Cook and Lewis (1963) found that big sagebrush *A. tridentata,* with its 5- to 11- foot taproot and wide laterally branched roots (Weaver and Clements 1938), strongly competed with crested wheatgrass. Robertson (1943) noted that sagebrush roots had a tendency to concentrate at depths of 15 cm. They reported that reinvasion of big sagebrush occurs in areas with good stands of crested wheatgrass subjected to light livestock grazing. Hyder (1954) reported that reinvasion of sagebrush in the Columbia River Basin following its control is to be expected. Sneva (1971) found that after 17 years "even when managed for minimal ecological impact that sagebrush will return" to crested wheatgrass seedings following chemical brush control in southeastern Oregon.

Frischknecht and Bleak (1957) reported in their study in northeastern Nevada that the reestablishment of sagebrush, following its control and seeding of grass, occurs immediately after the brush is removed. They also found that seeded bluebunch wheatgrass was more likely to permit big sagebrush recruitment than crested wheatgrass stands in similar condition. However, a report by Reichenberger and Pyke (1990) indicated that bluebunch wheatgrass was a stronger competitor than crested wheatgrass on a mountain Wyoming big sagebrush site.

Caldwell et al. (1991) indicated that mountain big sagebrush competed more successfully with bluebunch wheatgrass than with Standard crested wheatgrass. They reported "the roots of *Artemisia* were generally two to three times more abundant in areas with *Pseudoroegneria* than in those with *Agropyron*."

Eissenstat and Caldwell (1988b) reported that Standard crested wheatgrass had greater competitive ability than bluebunch wheatgrass when they used Wyoming big sagebrush transplants as indicator plants. The big sagebrush plants had "lower survival, growth, reproduction, and late-season water potential in monospecific stands of crested wheatgrass than the neighborhoods of bluebunch wheatgrass." Crested wheatgrass, which has thinner roots, "has approximately twice the root length and exhibits greater root growth in winter and early spring than bluebunch wheatgrass" (Eissenstat 1986). Eissenstat and Caldwell (1988a, 1988b) concluded that the "rapid water extraction by crested wheatgrass is probably a major factor when comparing its ability with bluebunch wheatgrass to compete with big sagebrush." In greenhouse tests Aguirre and Johnson (1991a, b) found that the greater root branching densities, lateral root lengths, and external link lengths enabled Hycrest crested wheatgrass to have a higher growth rate than Whitmar bluebunch wheatgrass.

Many crested wheatgrass seedings evaluated by Evans et al. (1986) became "infested with sagebrush and rabbitbrush within 5 to 10 years following establishment. Brush infestation, which may be as heavy as 20 to 25% crown cover, drastically reduces forage productivity of associated grasses. Data are limited, but one estimate of reduction is that each 1% increase of sagebrush crown cover was equivalent to a decrease of 4.5% in forage production when crown cover varied from 0 to 22% (Rittenhouse and Sneva 1976).

Cook and Lewis (1963) studied big sagebrush competition with crested wheatgrass, intermediate wheatgrass, and tall wheatgrass on the foothill rangelands near Eureka, Utah. Some 71% of the reinvaded sagebrush had been established within two years of initial brush removal. Big sagebrush densities ranged from 14.9 to 32.1 plants per 100 square feet. Depths at which root concentrations occurred were approximately the same (51-58 inches for the wheatgrasses and 60 inches for older sagebrush). Soil moisture was significantly higher on sites where the big sagebrush had been sprayed during the first two years of the study. Grass height and leaf length were also greater the first two years on sagebrush controlled sites than in the third year following sagebrush control.

Hull and Klomp (1967) found that Fairway crested wheatgrass became more dense and plants spread to adjacent areas in their studies in southern Idaho from 1954 to 1966. These findings agree with the conclusions of Weintraub (1953) that crested wheatgrass reseeds itself well on western rangelands. Hull and Klomp (1967) found that crested wheatgrass spread to rocky areas, waste places and sagebrush range where it was not originally seeded on the Blackfoot and American Falls sites in 1933 and 1932, respectively. At the Dubois site it was found 120 feet from their 1932 and 1933 initial plots. Standard, Fairway, and Siberian crested wheatgrasses were planted in 1946 at Dubois and had spread 169, 438, and 131% respectively by 1963. However, they noted that the spread of Siberian wheatgrass was erratic.

Several plant material scientists have documented sites where crested wheatgrass has not spread. They note 40 year old crested wheatgrass plants with "no evidence of progeny established around the original plants in the Great Basin." Others have noted in the Northern Great Plains that crested wheatgrass rarely spreads to adjacent native grasslands (USDA-ARS 1992).

Nissen (1994) and others (Pudney 1994, Harrison 1994) noted that Nordan and Siberian wheatgrasses coexist with natives such as bluebunch wheatgrass, Sandberg bluegrass and others in seedings after fire (some are 15 years old). On the Yakima Training Center in Washington, they note that crested wheatgrass did not appear to spread or compete with native species.

Rummell (1946) reported that species such as crested wheatgrass, which germinate early in the season and make rapid growth following emergence, can resist cheatgrass competition more successfully than that developed more slowly such as western wheatgrass. Harris (1965) found similar results with bluebunch wheatgrass, but reported that cheatgrass out competes bluebunch wheatgrass seedlings by extending its roots more rapidly during the winter, thus gaining control of the site before bluebunch seedlings become established. Cheatgrass matured four to six weeks earlier and utilized the limited moisture supply prior to use by bluebunch. Douglas et al. (1960) found that Whitmar bluebunch wheatgrass established slower than crested wheatgrass and that it took seven or more years to produce the same amount of vegetation.

Hart et al. (1983) found in their study near Cheyenne, Wyoming, that cattle stocking rate doubled when using crested wheatgrass with native range as compared to native range alone. The native range was dominated by bluegrama (*Bouteloua gracilis* [H. B. K.] Lag. ex Griffiths), western wheatgrass, sedges (*Carex* spp.), and needle-and-threadgrass (*Stipa comata* Trin. and Rupt.). Use of crested wheatgrass reduced livestock pressure on the native range and promoted more rapid recovery. Although some invasion of native species occurs in crested wheatgrass stands, many have remained productive 20 to 45 years (Asay and Knowles 1985; Dillman 1946; Hull and Klomp 1966; Cook 1966).

Asay and Johnson (1983) and Horton (1994) reported that planting various wheatgrasses, particularly crested wheatgrass, is effective in controlling annual weeds like cheatgrass. However, Monsen and Shaw (1983) and Walker, et al. (1993) questioned whether introduced perennials are compatible with most native species and suggested they may hinder native plant recovery. Elliot and White (1987) reported that crested wheatgrass competed with ponderosa pine seedlings (*Pinus ponderosa* Laws) for moisture and available nitrogen in their study near Flagstaff, Arizona.

Crested wheatgrass roots have the ability to grow at colder temperatures than bluebunch wheatgrass roots (Harris and Wilson 1970; Eissenstat 1986; Eissenstat and Caldwell 1988a).

Frank (1983) reported that western wheatgrass (*Pascopyrum smithii* [Rudd] A. Löve) has the ability to maintain a higher leaf water potential than crested wheatgrass and through its reduced growth rate during drought, it remains green longer than crested wheatgrass. Frank (1994) found increases in the amino acid proline during the later stages of plant development, and suggested that it may condition western wheatgrass to better tolerate water stress than crested wheatgrass. Cook and Harris (1968) found that crested wheatgrass produced earlier growth than either western wheatgrass or beardless wheatgrass and matured to the seed shattering stage in less time. In comparing invasive root growth into disturbed soil by crested wheatgrass and bluebunch wheatgrass, Eissenstat and Caldwell (1989; 1988a) found that crested wheatgrass invaded "more rapidly into the newly available soil ..." and in early spring when soils are cold.

Crested wheatgrass and bluebunch wheatgrass extracted phosphorus and water at similar rates in the early spring. However, later in the spring, crested wheatgrass had greater extraction rates than bluebunch wheatgrass (Eissenstat 1986; Eissenstat and Caldwell 1988b). Eissenstat and Caldwell (1989) suggested that crested wheatgrass reduced phosphorus uptake by neighboring Wyoming big sagebrush (Beetle 1961) plants more effectively than bluebunch wheatgrass.

Pyke (1990) reported that seed production was much greater for crested wheatgrass than bluebunch wheatgrass. Crested wheatgrass not only produced more seed than bluebunch wheatgrass but produced nearly the same amount in dry years while bluebunch wheatgrass produced none at the study area in northwestern Utah. Pyke (1990) further noted that bluebunch wheatgrass seeds were dispersed when they matured, while crested wheatgrass "retained some seeds and dispersed them slowly throughout the year," which allowed seeds of crested wheatgrass to escape peak periods of seed predation. He noted that seeds were carried over beyond one year for crested wheatgrass but not for bluebunch wheatgrass. Pyke (1990) suggested that "Demographic factors associated with seeds of crested wheatgrass seemed to favor maintenance and spread into native stands formerly dominated by bluebunch wheatgrass." Roché (1994) and Pudney (1994) found that crested wheatgrass out competed bluebunch wheatgrass in established stands in eastern Washington.

Crested wheatgrass was planted in a mixture dominated by green needlegrass (*Stipa viridula* Trin.) and western wheatgrass in 1940 on cultivated land in Prairie County, Montana, and was grazed for 18 years. Herbage yield was greater for native grasses than for crested wheatgrass. Green needlegrass increased and encroached on the adjoining crested wheatgrass strips with spring and winter grazing (McWilliams and Cleane 1960).

Caldwell et al. (1981) found that crested wheatgrass had better recovery from defoliation than bluebunch wheatgrass, and this difference appeared to be related to rapid growth of new tillers in crested wheatgrass. Crested wheatgrass used less nitrogen and had less biomass per unit area of photosynthetic tissues. It had more tillers and leaves per bunch and shorter stems than bluebunch wheatgrass, all of which apparently contribute to a greater tolerance to defoliation.

Zamora (1994) found that crested wheatgrass had declined six years after planting in a mixture with Whitmar bluebunch wheatgrass and numerous natives including snowberry (*Symphoricarpos* spp. Juss), balsam root (*Balsamorhiza sagittata* Pursh), western yarrow (*Achillea lanulosa* Nutt.), penstemon (*Penstemon* spp. Mitch), blue elderberry (*Sambucus coerulea* Raf Juss), and annuals at the Midnight Mine 60 miles northwest of Spokane, Washington.

Keller (1979) concluded that squirreltail may provide vigorous competition for crested wheatgrass. He found that it also invades both cheatgrass and medusahead stands (*Taeniatherum caput medusae* [L] Nevski spp. *asperum,* formerly *Elymus caput-medusae* L.).

Roché et al. (1994) established plots of Nordan crested wheatgrass (bunchgrass), Oahe intermediate wheatgrass and Luna pubescent wheatgrass (sod formers) during the fall of 1970. Their study showed that summer and fall-clipped sod-former grasses allowed less yellow starthistle survival than spring-clipped grass plots. Yellow starthistle plants growing with grass litter and standing crop were weaker and more spindly than in the grass free plots. Apparently a stand of adapted introduced perennial grasses, such as intermediate wheatgrass in eastern Washington, can limit yellow starthistle if the grasses can be managed to provide shade to the soil surface from fall through spring and deplete soil water in late spring through summer.

Pyke and Archer (1991) suggested that both stress tolerance and competitive ability should be considered when evaluating competition factors in an environment. They noted that crested wheatgrass was tolerant to drought and other limited resources.

3.2) Wildlife Usage

Austin et al. (1994) noted that mule deer preferred Fairway crested wheatgrass in the spring and fall over several other plants including natives. Austin et al. (1983) reported the impact of spring livestock grazing on crested wheatgrass as it relates to winter use by mule deer. Willms and McLean (1978) found in British Columbia that green crested wheatgrass was second in importance to Sandberg bluegrass in mule deer diets during 6 March to 5 May and the most important in their diet from 6 to 31 May.

Crested wheatgrass seedlings often provide high-quality forage for wildlife grazers that aids in rapid recovery of body condition lost during the stressful winter period. Seeded species can supply significant amounts of green herbage on many sagebrush winter ranges where native species are either dormant or low in availability. Fall growth of crested wheatgrass may supply quality forage in fall and snow-free periods during the winter, extending the availability of browse for winter forage. Seeding of introduced grass species on spring-fall range resulted in reduced browse use by livestock and reduced competition with wildlife (Lamb 1966, Vale 1974) (Appendix II).

Both the use of crested wheatgrass by deer (Urness, 1983) and antelope and its nutritional value vary by region and locality (Urness, 1986). Green growth from crested wheatgrass is important from fall to mid-spring in supplementing browse diets. Such seedings have helped to reduce use conflicts between deer and livestock on foothill ranges. Antelope receive less direct value from crested wheatgrass seedings because of their dependence on forbs. When available, crested wheatgrass seedings are heavily used by elk and bighorn sheep (Urness, 1986).

Heady (1988) in summarizing the evaluation of the "Vale Rangeland Rehabilitation Program" reported that "the program did not help or harm wildlife and perhaps resulted in an improved wildlife habitat overall." He noted that "deer and antelope numbers seem to have increased in response to the reduction of tall brush and the increase of winter forage made available by fall growth of crested wheatgrass." Ground squirrels and probably their predators were maintained due to the increase of perennial grass areas. However, black-tailed jackrabbits may have been adversely affected by a reduction in sagebrush. Kindschy (1986) found that sage grouse declined in the Vale program area because of the reduction of sagebrush. Bobcat numbers were down but eagle numbers increased.

Use of crested wheatgrass seedings by black-tailed jackrabbits in the southern half of Curlew Valley on the Utah-Idaho border were studied by Westoby and Wagner (1973). Their studies showed that approximately 70% of total forage removed from the crested wheatgrass seeding by rabbits was concentrated in "a 300 meter- wide band around the perimeters. Estimated forage removal within this 300-meter band was 60 kg/ha/yr. This is less than 10% of nearly all the yield values found, including those in poor years, in comparable seedings in this area." This finding indicates that even when jackrabbit densities are high, they may not cause serious damage to established crested wheatgrass seedings.

Use of Nordan crested wheatgrass and Hycrest crested wheatgrass (a hybrid between Standard and Fairway crested wheatgrasses) by black-tailed jackrabbits was nearly twice that of Magnar and Trailhead basin wildrye *(Leymus cinereus,* [Scribner and Merr] A. Löve); Secar and Goldar bluebunch wheatgrass; #9021076 thick-spike wheatgrass (*Elymus lanceolatus* [Scribn. and Smith] Gould) selection; and Bozoisky Russian wildrye (*Psathyrostachys juncea* [Fisch] Nevski) (Ganskopp et al. 1993). Seeding of unpalatable cultivars are suggested to: (1) discourage jackrabbit presence in right-of-ways where they pose a danger, (2) to reduce competition between jackrabbits and livestock for forage, or (3) reduce potential damage to ground cover or forage resources in critical areas during jackrabbit population peaks. Conversely, seedings of palatable cultivars might be used to lure jackrabbits away from less palatable, but more valuable crops or forages."

Shrub-dependent nongame bird species were displaced when crested wheatgrass seedings were established in sagebrush communities (McAdoo et al. 1986). However, ground-nesting species increased in response to improved herbaceous cover. The ground nesting birds are adapted to this grass species life form or structure. "Total bird abundance in the seeding may be similar to that of unconverted sagebrush habitat, but total number of species is lower and relative abundance of species is much different in the monoculture seeding." As crested wheatgrass returns to sagebrush shrub-nesting bird species increase. Change in prey species populations resulting from change in shrub and herbaceous cover may affect raptor distribution, nesting success etc. In some cases prey abundance and vulnerability increase after conversion while in other cases reinvading sagebrush provides food and cover for other different prey species (especially rabbits and rodents).

Nongame bird populations (shrub and grass nesters) were studied at 8 sites (sagebrush-invaded crested wheatgrass, monoculture crested wheatgrass, or unconverted sagebrush) in central Nevada (McAdoo et al. 1986). Abundance of the shrub and grass nesters respectively were: in monoculture crested wheatgrass seedings - 18.0 and 82.0%; sagebrush invaded seedings - 48.3 and 51.7%; and unconverted sagebrush - 79.8 and 20.2%. The relative abundance of the different communities of birds were related to the amount of sagebrush (McAdoo et al. 1986).

"Habitat use and food selection data were collected for deer mice *(Peromyscus maniculatus)*, montane voles *(Microtus montanus),* Ord's kangaroo rats *(Dipodomys ordii),* and Townsend's ground squirrels *(Spermophilus townsendii)* near a sagebrush/crested wheatgrass interface in southeastern Idaho." The total captures in each habitat type were: 37% in the native sagebrush, 33% in disturbed/unseeded sites, and 30% in crested wheatgrass. Montane voles were almost exclusively associated with crested wheatgrass. The Ord's kangaroo rat used crested wheatgrass substantially (high was 82% and 91% in July and August, respectively). Crested wheatgrass use by deer mice was highest at seed set and less preferred in June. Crested wheatgrass made up the bulk of the diet of the ground squirrel. These four mammal species are either absent or are uncommon in the native sagebrush type, but they comprise a large part of the mammal community on the seeded site (Koehler and Anderson 1991).

Deer mice behavior, including nesting and food storage, was observed on 21 crested wheatgrass pastures (100 acres each) on the Benmore Experiment Station south of Tooele, Utah. Mice or nests were found on one-half and one-third of the plots where grass utilization was less than 50% or more than 50%, respectively. Food in caches consisted mainly of mature heads of crested wheatgrass, and small bulbs of bulbous bluegrass. While the mice occupied only one shelter per plot, they had nests and food caches under other shelters in the same plot. Plant fiber was used in nest construction (Frishknecht 1965).

A study on the food habits of rodents in sagebrush and shadscale associations was conducted in the Raft River Valley of southern Idaho. Seeds and vegetative parts of crested wheatgrass were frequently eaten during August by the western harvest mouse. The greatest numbers of western harvest mice were also trapped in stands of crested wheatgrass (Johnson 1961).

Live small mammal trapping studies conducted in 1978-79 at the Idaho National Engineering Laboratory in southeast Idaho revealed that small mammal densities on Surface Disposal Areas (SDA) seeded with crested wheatgrass equaled or exceeded those in the adjoining sagebrush. Later studies of 1988-89 confirmed that small mammal densities were highest along the SDA edge where an earthen dike separated the seeded SDA from the native sagebrush. Small mammal densities were much less in the interior of the SDA than on the edge of the SDA. During this study, small mammal densities appeared to vary less on or around the SDA than in the adjoining native sagebrush (Boone and Keller 1993).

3.3) Summary

Crested wheatgrass is well adapted to much of the western United States. The crested wheatgrass taxa are generally long lived on adapted sites in the Columbia River drainage. Some plantings in the Great Basin have been reported to be more than 50 years old, while other well established stands of crested wheatgrass seedlings have died out after 5 to 15 years. These areas are generally low or high in precipitation.

In areas where full stands were established and proper management was applied to maintain a monoculture, crested wheatgrass is competitive and withstands native grass and forb encroachment. However, big sagebrush and rabbitbrush often invade crested wheatgrass seedings, especially in those instances where seed sources are nearby. Some researchers have noted that brush species do not invade large crested wheatgrass seedings when seed sources are nonexistent.

Researchers differ in their opinion regarding the invasiveness and spread of crested wheatgrass. Some have not found it to spread in specific areas while others have recorded its spread. However, most agree that in areas where it has spread or invaded native sites, it moved very slowly.

Many small birds and rodents eat crested wheatgrass seeds; mule deer and elk eat green crested wheatgrass forage in early spring and early fall.

Eurasian species such as cheatgrass and Russian thistle have been a part of the Columbia River basin flora for more than a century. Most originated in the semiarid regions of Eurasia, where they had been subjected to millennia of various intensities of anthropogenic disturbance. Many of the taxa in the crested wheatgrass complex also originated in Eurasia and therefore have capabilities to compete well with unintentionally introduced taxa like cheatgrass and Russian thistle.

HARD AND SHEEP FESCUE

1) TAXONOMY AND ORIGIN

Although hard fescue is most certainly not native to North America, the specific scientific name remains enigmatic. Older treatments (e.g., Hitchcock 1935, 1951; Piper 1906) of the genus *Festuca* in North America included early introductions of hard fescue to *Festuca ovina* C. von Linné var. *duriuscula* (C. von Linné) Koch, and most regional floras and other works followed accordingly. As discussed by McNeill and Dore (1976), the type specimen of *F. ovina* var. *duriuscula* is actually a plant of the *F. rubra* complex; consequently, the names *F. duriuscula* and *F. ovina* var. *duriuscula* have been misapplied to hard fescue.

The logic involved in finding the appropriate valid and available name depends entirely upon the taxonomical concepts and predilections of individual taxonomists from Europe and North America. Within the Flora Europeae, Markgraf-Dannenberg (1980) recognized 115 species and numerous additional infraspecific taxa in the *F. ovina/F. rubra* aggregate employing putatively diagnostic combinations of ploidy, rhizome elongation, degree of sheath margin connation, and spikelet bract variation, together with such esoteric character-states as position and amount of leaf-blade sclerenchyma or percentage of leaf-blade epidermal stomata with accompanying silica cells. As a consequence, *F. ovina* C. von Linné *sensu stricto* is applied exclusively to diploid ($2n = 2x = 14$) plants of northern and central Europe, only weakly differentiated from diploid plants of Asia and North America, arbitrarily segregate as different species.

More recent treatments of the *F. ovina/F. rubra* aggregate in North America (e.g., Aiken and Darbyshire 1990; Dore and McNeill 1980; Gleason and Cronquist 1991) have accepted the narrower, vague Eurasian specific definitions, and have relegated *F. ovina sensu stricto* to alien status. As a consequence, a misconception is now circulating among North Americans that no portion of the *F. ovina/F. rubra* aggregate is indigenous to North America, an interpretation that is incorrect. The *F. ovina/F. rubra* aggregate is without question circumboreal, and whether the indigenous populations of North America are treated as a single polymorphic species, or split into the 10 native species recognized by Aiken and Darbyshire (1990), the origin of these populations is not in question.

In Europe, the common name hard fescue is loosely applied to a group of hexaploid ($2n = 6x = 42$) *F. ovina* segregates, primarily *F. brevifolia* Tracey, *F. guestfalica* Bönninghausen *ex* Reichenbach, and *F. lemanii* Bastard. Hard fescue introductions to North America may be treated taxonomically as alien material of *F. ovina sensu amplissimo*, or as one of five, or possibly more, segregate species depending upon the subtle morphological differences exhibited by individual plants. Appropriate valid scientific names are listed below:

1.1) Scientific Names

Festuca brevifolia Tracey, Plant Syst. Evol. 128: 287. 1977.
Festuca carnuntina Tracey, Plant Syst. Evol. 128: 289. 1977.
Festuca glauca Villars, Hist. Pl. Dauph. 2: 99. 1787.
Festuca guestfalica Bönninghausen *ex* Reichenbach, Fl. Germ. Excurs. 140. 1831.
Festuca lemanii Bastard, Essai Fl. Maine et Loire. 36. 1809.
Festuca ovina C. von Linné, Sp. Pl. ed. 1: 73. 1753 *sensu amplissimo*.
Festuca ovina C. von Linné var. *trachyphylla* (Hackel) Druce, List Brit. Pl. 83. 1908.
Festuca ovina C. von Linné subvar. *trachyphylla* Hackel, Monogr. Festuc. Eur. 91. 1882.
Festuca duriuscula auctorum non C. von Linné [= *F. rubra* C. von Linné *sensu amplo*]
Festuca ovina C. von Linné var. *duriuscula auctorum non* (C. von Linné) Koch [= *F. rubra* C. von Linné *sensu amplo*]
Festuca trachyphylla Hackel *ex* Druce, Rep. Bot. Exch. Cl. Brit. Isles 1914(4): 30. 1915. [= *F. dumetorum* Philippi, Linnaea 33: 297. 1864, *non* C. von Linné, Sp. Pl. ed. 2: 109. 1762.]
Festuca trachyphylla (Hackel) Krajina, Acta Bot. Bohem. 9:191. 1930, *non* Hackel *ex* Druce, Rep. Bot. Exch. Cl. Brit. Isles 1914(4): 30. 1915.

1.2) Other Common Names

Hard sheep fescue, sheep fescue

1.3) Cultivar Names

DURAR, COVAR

2) Common Uses

Soil erosion control, pasture, turf, watershed protection, roadside beautification, airports, dams sites, terraces, diversions, ditchbanks, mine spoils, soil builder, ski slopes.

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Aiken and Darbyshire (1990) agreed with researchers in Europe that *Festuca trachyphylla* successfully invaded habitats disturbed by humans in central Europe. "Vigorous establishment in early successional habitats was undoubtedly a character recognized as valuable in its early selection as a turf and pasture plant. Through commercial seeding and naturalization, the distribution of *F. trachyphylla* now extends into most of Europe and North America."

Durar hard fescue (*Festuca thuillier longifolia* formerly *Duriuscula ovina*) has extensive root production. It has been used for soil stabilization and watershed protection, and is well adapted in the 38-60 cm precipitation zone (Ensign 1985). Gomm (1974) reported the success of *F. ovina longifolia* in the lodgepole pine-Douglas fir forest-grasslands of western Montana in an area where Idaho fescue is dominant. Gomm (1994) found that hard fescue persisted at Smoot, Wyoming after 14 years, but did not compete with natives.

The competitive character of Durar hard fescue was demonstrated in a 1940 planting at Pullman, Washington, where five pounds of crested wheatgrass and five pounds of hard fescue were planted. Durar increased from 2% in 1940 to over 90% in four years, and by six years it had completely suppressed crested wheatgrass (Schwendiman et al. 1964). Several later Durar plantings, including those made by highway departments of Washington and other states, exhibited its suppressive abilities by outcompeting cheatgrass and other annuals. Durar's massive root system, which was measured at Pullman to be 7,500-15,000 pounds per acre, allows it to strongly compete with other species (SCS, PPMC files researched 1994).

Durar hard fescue was seeded in individual plots along with 61 other species or cultivars at the following locations in Washington: Republic 1948, 1949, 1950, 1951; Riverside 1950 and 1951; and Harrington 1950. By 1978 Durar hard fescue controlled almost half of the seeded area at the 3 forgoing sites (Harris and Dobrowolski 1986).

Roché (1994) found after 20 years Durar hard fescue seeded plots were invaded and completely taken over by pinegrass and elk sedge on Grand and Douglas fir sites.

Covar sheep fescue is a selection from Turkey. It has high root production and once established is very competitive and valuable as an understory grass where native fescues grow. "Covar suppresses brush invasion following burns in chaparral communities" (Ensign 1985). Carlson (1994) noted in a 45-year-old seeding that Covar sheep fescue stopped the encroachment of deer brush *(Ceanothus* sp.) south of Baker, Oregon.

Both Durar hard fescue and Covar sheep fescue are very competitive after they are established and generally become a monoculture. Covar, which is adapted to the 10 to 18 inch rainfall areas in the Columbia Basin, is more drought tolerant than Durar. Replicated row plantings of the two cultivars made 35 years ago by the Soil Conservation Service can still be seen. Encroachment by other plants into their established areas seldom occurs. Covar and Durar are the most aggressive plants used in northern Idaho to compete with spotted knapweed (*Centaurea maculosa* Lam.). However, Covar is not a strong invader and spreads very slowly by seed and has not been noted to take out native stands (Carlson 1994, Gibbs 1994, Krueger 1994, and Ogle 1994). Kelly (1994) found cascade trefoil (*Lotus* L.), Canadian thistle (*Cirsium arvense* [L.] Scop) and smooth brome (*Bromus inermis* Leyss.) to invade Covar sites. Kelly also found that after 20 years Covar spread to other plots at the Central Ferry site on the Snake River in central Washington. However, it did not spread at Lind, Washington. Gates and Robocker (1960) found sheep fescue, along with other introduced grass species, had little or no effect on dalmatian toadflax.

Monsen and Anderson (1993) observed that *Festuca ovina* ssp. *sulcata* persisted for 52 years on a big sagebrush site in south-central Idaho, in the Boise National Forest. Another three ecotypes failed to survive for 10 years.

3.2) Wildlife Usage

Goebel and Berry (1976) conducted feeding trials for seed preference by 25 different wild birds in an annual-dominated *Agropyron-Poa* habitat type near Asotin, Washington. Six perennial and two annual species were tested. In a cafeteria-type feeding experiment during the spring of 1969 they found that the small seeded sheep fescue was removed more frequently than larger-seeded perennials such as intermediate and pubescent wheatgrass. Intermediate wheatgrass was the most preferred wheatgrass used in these trials. Results from this study suggest that birds may inhibit improvement of range sites by heavy utilization of the seed.

Durar hard fescue has been found to encourage rodent activity. Although Durar and Covar fescues are not highly preferred by herbivores, both mule deer and elk graze Covar sheep fescue in early spring (Gibbs, 1994).

3.3) Summary

Durar hard fescue and Covar sheep fescue when established in their adapted habitat have developed monocultures and persisted up to 50 years. They both have a dense spreading root system and have the ability to exclude most invading plants. Nevertheless, rhizomatous plants have encroached into their stands. The spread or non-spread of hard and sheep fescues into adjacent areas appears to be site specific. Rodents use Durar hard fescue as a habitat. Elk and mule deer graze sheep fescue in the early spring, and wild birds use sheep fescue seed.

INTERMEDIATE WHEATGRASS/PUBESCENT WHEATGRASS COMPLEX

1) TAXONOMY AND ORIGIN

Because of often radically different taxonomical treatments by regional authors for the Triticeae tribe, most wheatgrass species now carry a permanent nomenclatural legacy reflecting multiple generic assignments, as evidenced by the varying valid assignments of the Eurasian intermediate wheatgrass/pubescent wheatgrass complex to six different genera. Regarding the recognition of intermediate wheatgrass and pubescent wheatgrass as separate species, Mariam and Ross (1972) and Dewey (1978) argued that the presence of copious trichomes on the leaf, spike, and spikelet bract surfaces, which supposedly segregates pubescent wheatgrass from intermediate wheatgrass is too variable among individuals of the same wild population to be consistently diagnostic. Consequently, most recent treatments, including those of Tzvelev (1976), Dewey (1984), and Löve (1984), treat pubescent wheatgrass as a subspecies of intermediate wheatgrass. Following is a list of equally valid scientific names and of the most commonly used cultivars.

1.11) Scientific Names

Agropyron intermedium (Host) Palisot de Beauvois, Essai Agrost. 102, 146. 1812.
Elymus hispidulus (Opiz) Melderis, Bot. J. Linn. Soc. 76:379. 1978.
Elytrigia intermedia (Host) Nevski, Trudy Bot. Inst. AN SSSR, ser. 1,1:14. 1933.
Thinopyrum intermedium (Host) Barkworth *et* D.R. Dewey, Am. J. Bot. 72:772. 1985.
Trichopyrum intermedium (Host) Á. Löve, Veröff. Geobot. Inst. Zürich 87:49. 1986.
Triticum intermedium Host, Gram. Austr. 3: 23. 1805.

1.12) Cultivar Names

AMUR, CLARKE, CHIEF, GREENAR, OAHE, SLATE, TEGMAR, RELIANT, MANSKA, REE

1.2) Pubescent Wheatgrass

1.21) Scientific Names

Agropyron barbulatum Schur, Verh. Siebenb. Ver. Naturw. 4:91. 1853.
Agropyron intermedium (Host) Palisot de Beauvois ssp. *trichophorum* (Link) Ascherson *et* Graebner, Syn. Fl. Mitteleur. 2:658. 1901.
Agropyron intermedium (Host) Palisot de Beauvois var. *trichophorum* (Link) Halácsy, Conspectus Fl. Græcæ 3:437. 1904.
Agropyron trichophorum (Link) K. Richter, Pl. Eur. 1:124. 1890.
Elymus hispidus (Opiz) Melderis ssp. *barbulatus* (Schur) Melderis, Bot. J. Linn. Soc. 76:381. 1978.
Elytrigia intermedia (Host) Nevski ssp. *trichophora* (Link) Á. Löve *et* D. Löve, Bot. Not. 114:50. 1961.; Tzvelev, Novit. Syst. Pl. Vasc. 10:31. 1973, *nomen superfluum*
Elytrigia trichophora (Link) Nevski, Tr. Sredneaz. Univ. ser. 8B, 17:61. 934.
Thinopyrum intermedium (Host) Barkworth *et* D.R. Dewey ssp. *barbulatum* (Schur) Barkworth *et* D.R. Dewey, Am. J. Bot. 72:772. 1985.
Trichopyrum intermedium (Host) Á. Löve ssp. *barbulatum* (Schur) Á. Löve, Veröff. Geobot. Inst.
Triticum trichophorum Link, Linnaea 17: 395. 1843.

1.22) Cultivar Names

GREENLEAF, LUNA, TOPAR

2) COMMON USES

Pasture, hay, soil erosion control, turf, wildlife, forage and habitat

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Cook and Harris (1968) reported that intermediate wheatgrass started spring growth the same time as western and beardless wheatgrass. It matured more rapidly than beardless wheatgrass, which in turn matured more rapidly than western wheatgrass.

Greenar intermediate as well as Topar and Luna pubescent wheatgrass did not compete with and were replaced by Sherman big bluegrass and Secar bluebunch wheatgrass in an overseeding test in 1977 at Lind, Washington. By 1991 they were completely replaced by the two later species. When seeded alone, Greenar intermediate and Topar pubescent did not survive and Luna pubescent had only 2% ground cover (Stannard 1994).

Hull and Klomp (1966) found that plots seeded in 1946 to intermediate and pubescent wheatgrass at the U.S. Sheep Experiment Station Dubois, Idaho had spread 155 and 210%, respectively, from their initial plantings. At the Arrowrock site 20 miles southeast of Boise, they found that intermediate and pubescent wheatgrass seeded in 1941 had spread considerably by 1963.

Asay and Knowles (1985) indicated that intermediate wheatgrass is known for its productivity during early years of the stand. Even though newer varieties of intermediate wheatgrass are better (Asay, 1994), "it has been criticized for its lack of longevity when mismanaged or subjected to environmental stress." They further noted that it was successfully used in mixtures with alfalfa.

Gomm (1994) found that intermediate wheatgrass did not spread into native range from a seedling that was established in 1980 at Star Valley, Wyoming. Oahe intermediate and Luna pubescent wheatgrass and Nordan crested wheatgrass caused plants of yellow starthistle to be weaker and more spindly (Roché et al. 1994) (See crested wheatgrass section for more detail).

Whitmar bluebunch wheatgrass was seeded in individual plots with 10 other species, including pubescent wheatgrass, in 1962 at the Yakima Training Center in Washington. By 1994 Whitmar bluebunch wheatgrass had encroached into several other plots and become the dominant species in the adjoining plot of pubescent wheatgrass (Nissen 1994).

Prather and Callihan (1991) developed a study to quantify interference of pubescent wheatgrass and yellow starthistle when pubescent wheatgrass was at the seedling stage. This laboratory experiment showed that "Pubescent wheatgrass provided 0.5 to 1.3 times as much intraspecific interference, plant for plant, as the interspecific interference caused by yellow starthistle. Yellow starthistle provided from 1.5 to 4.6 times as much intraspecific interference, plant for plant, as the interspecific interference caused by pubescent wheatgrass. Aggressivity of either yellow starthistle or pubescent wheatgrass was density dependent. Intraspecific interference by both yellow starthistle and pubescent wheatgrass became stronger than interspecific interference as density of both species increased. Interference with yellow starthistle growth was dominated by the intraspecific component whenever densities of the two species were equal, indicating that yellow starthistle would not be excluded by seedlings of pubescent wheatgrass. Interference with pubescent wheatgrass growth was dominated by intraspecific effects when the densities of pubescent wheatgrass and yellow starthistle were equal when the population density of each species was about 290 plants/m^2."

Weekly leaf counts showed that intra- and interspecific interference with yellow starthistle and pubescent wheatgrass was noticeable at 6 and 7 weeks after emergence, respectively. Only number of leaves on pubescent wheatgrass was correlated to soil moisture at 10 cm depth which may be the reason for the greater competitive ability of yellow starthistle. When densities of the two species were equal it was concluded that yellow starthistle would not be excluded by seedlings of pubescent wheatgrass. "Yellow starthistle control during establishment of pubescent wheatgrass would be needed for optimal pubescent wheatgrass establishment; however, a substantial increase in seeding rates of pubescent wheatgrass may also enhance its establishment by increasing its aggressivity." "Yellow starthistle was the better competitor in this experiment and was subjected to more intense intraspecific effects than interspecific effects at all densities. Pubescent wheatgrass has greater longevity and, after becoming well established, may be able to deny resources to yellow starthistle seedlings, ensuring it is not excluded from the site."

Competition of intermediate wheatgrass and other introduced grass species with big sagebrush was studied on foothill rangelands near Eureka, Utah (Cook and Lewis 1963). Soil moisture was significantly higher on sites where the big sagebrush had been sprayed during the first two years of this study. Depths at which root concentrations occurred were essentially the same. Increasing sagebrush maturity resulted in reduced grass height and leaf length.

Monsen and Anderson (1993) designed a study "to investigate the longevity of a number of introduced and native grasses (132 accessions) and to evaluate variability in plant longevity among ecotypes." The study site was located on a protected "mountain big sagebrush-bluebunch wheatgrass site in south-central Idaho, Boise National Forest." Introduced grasses studied included tall, pubescent, and intermediate wheatgrasses, Siberian, Fairway, and Standard crested wheatgrasses, and sheep fescue.

"Of the 132 accessions planted in 1939 by USFS, 40 survived 10 years. The 40 accessions included 34% of the introduced species, 38% of the indigenous species, and 18% of species native to the general area. Thirty two years after seeding only 21 accessions survived, which included 19% of the introductions, 27% of the indigenous species, and 3% of the general native species." In 1991, 52 years after planting, 14 accessions persisted. No native species and only 15% of the introductions and 15% of the indigenous remained. After 52 years the following introduced grass plant accessions were rated the most successful: intermediate wheatgrass, sulcata sheep fescue, and Fairway crested wheatgrass. "Most ecotypes of intermediate wheatgrass, including pubescent wheatgrass survived for 52 years, but some were less abundant than others. Three ecotypes of sheep fescue failed to survive for 10 years, but one was ranked highly successful. Fairway crested wheatgrass was much more abundant and persistent than Standard crested wheatgrass. Most ecotypes of intermediate wheatgrass were aggressive, long-lived, and extremely persistent perennials. Ecotypes of crested wheatgrass vary in longevity. Fairway crested wheatgrass is better adapted to more mesic big sagebrush communities than is Standard crested wheatgrass."

Bartels (1992) provided an indepth analysis "on the competitive interactions between intermediate wheatgrass and western wheatgrass" in central Utah. This study showed "that during the dry years 1987 to 1990 western wheatgrass was competitively superior to intermediate wheatgrass under short-duration grazing or when protected from grazing. Removal of western wheatgrass from the interface led to an improvement in the performance of intermediate wheatgrass over a wide range of environmental conditions...i.e., improved phytomass production, increased tiller densities, higher tiller weights, and improved ramet (tiller) recruitment. The only significant declines in tiller density of intermediate wheatgrass during these two years (June 1988-June 1990) were found in the nonirrigated plots where it competed with western wheatgrass. Because of the impact of competition on ramet survival and recruitment, ramet density of western wheatgrass increased at the interface of the two species while that of intermediate wheatgrass declined, irrespective of the defoliation regime. During the three years of this study and under protection from grazing, western wheatgrass eliminated intermediate wheatgrass from the interface." The reasons for the competitive superiority of western wheatgrass include: "leaf rolling (Latas and Nicholson 1976), glaucousness, more rapid conditioning to drought (Frank 1983), greater allocation of photosynthates to growth and maintenance of the root system (Power 1985), extraction of more water from deeper soil depths (Frank et al. 1985), and deeper root penetration in western wheatgrass." These species also have "dissimilar, genetically programmed tiller dynamics" that "may have contributed to the superior competitive ability of western wheatgrass." "Populations of western wheatgrass and intermediate wheatgrass are generally spatially segregated, occurring in monospecific patches, which strongly suggests a process of competitive exclusion between these two species with similar resource demands." In any case it appears that the native western wheatgrass is more competitive and, in fact, will crowd out the introduced intermediate wheatgrass.

3.2) Wildlife Usage

Everett et al. (1978) found that captive deer mice from pinyon-juniper, sagebrush-bitterbrush (*Purshia tridentata* [Pursh] DC), and Jeffrey pine-ceanothus plant associations ate or destroyed an amount of seed equivalent to approximately one-third of their body weight each day. The comparative seed preference rankings for four introduced grasses (stiffhair wheatgrass, pubescent wheatgrass, Fairway crested wheatgrass, sheep fescue, and bulbous bluegrass) were 10th, 19th, 23rd and 24th, respectively. Twenty-eight native and introduced plant species were evaluated (including eight grass species). The indicated rankings were relatively low except for stiffhair wheatgrass. Rodent seed consumption under field conditions may differ because of seed supply and nutritional requirements. Everett et al. identified the advantage of using seed which is not preferred by deer mice in areas where deer mice are problematic.

Kangaroo rats and black-tailed jackrabbits show a preference to Greenar intermediate and Luna and Topar pubescent wheatgrass compared to other grasses at the 1965 Coffee Point Sage Grouse Habitat Improvement Field Evaluation Planting near Aberdeen, Idaho (Hoag, 1994).

Goebel and Berry (1976) conducted feeding trials for seed preference by 25 different wild birds in a annual-dominated *Agropyron-Poa* habitat type near Asotin, Washington. Six perennial and two annual species were tested. Based on cafeteria-type feeding stations during the spring of 1969, they found that the small sheep fescue seed was removed more frequently than larger seeds such as intermediate and pubescent wheatgrass. Intermediate wheatgrass was the most highly preferred wheatgrass used in these trials. They concluded that birds may inhibit seedling establishment by consuming planted seeds. Horton (1994) observed significant consumption of planted seeds by birds in northwestern Utah.

Austin et al. (1994) found that Luna pubescent wheatgrass is highly preferred by mule deer in both spring and fall. Seeding of introduced grass species, such as intermediate wheatgrass, on spring-fall range reduce browse use by livestock, which reduced their competition with wildlife (Appendix II).

3.3) Summary

Intermediate is a long-lived grass (50+ years) that may outlive associated natives and other introduced species. The competitive ability and invasiveness of the intermediate wheatgrass complex is highly dependent upon environmental conditions and use. However, Sherman big bluegrass and western wheatgrass have a competitive superiority over some of the introduced species in this complex. Other studies have shown that these introduced species successfully outcompete yellow starthistle when intermediate wheatgrass densities are high enough. Competition from big sagebrush effectively reduced both grass height and leaf length. Some studies showed that intermediate wheatgrass may spread into adjoining vegetative communities while other studies have shown no plant expansion. In many instances, it coexists with native taxa and thus adds to the degree of biodiversity.

KENTUCKY BLUEGRASS

1) TAXONOMY AND ORIGIN

Controversy still exists as to whether all populations of Kentucky bluegrass, *P. pratensis* C. von Linné, are foreign to North America, or whether some native populations (segregated as

P. agassizensis Boivin & Löve) existed along the Cascade-Sierra Nevada Cordillera, the Rocky Mountain Cordillera, and northern Canada, prior to either intentional or accidental spread of European cultivars by Euro-American farmers and ranchers during the past three centuries (see Duell [1985] for discussion regarding North American populations). The *P. pratensis* complex comprises genes manifesting an inherently elevated degree of phenotypic plasticity, likely derived from rather pronounced polyploidy ($2n$ = 21-147; x = 7) through repeated introgression with various close relatives. Resultant morphs are maintained through pseudogamic, facultative apomixis, with infrequent allogamy (Clausen 1961). Across much of western North America, two rather distinctive morphs are easily recognized: the first has culms to about one-meter tall, and panicles openly pyramidal, ultimately nodding and tawny; the second with culms typically three decimeters or less, and panicles densely contracted, oblongly linear, erect, and purplish to some degree. Whatever the origin of Kentucky bluegrass may be on the North American continent, this species seems assuredly foreign to the indigenous Columbia Basin flora. Early floras of the Palouse Region (Piper and Beattie 1901) and of southeastern Washington (Piper and Beattie 1914), as well as early Bulletins of the Idaho Agricultural Experiment Station (Henderson 1903) list Kentucky bluegrass as "everywhere introduced."

1.1) Scientific Names

Poa agassizensis Boivin *et* D. Löve *in* D. Löve *et* Bernard, Svensk Bot. Tidskr. 53:371. 1959, *nomen nudum*; Boivin *et* D. Löve, Nat. Canad. 87:176, *fig. 1*. 1960.

Poa pratensis C. von Linné, Sp. Pl. ed. 1:67. 1753.

1.2) Other Common Names

Meadow grass, smooth meadow grass, June grass, speargrass, bluegrass

1.3) Cultivar Names

COLUMBIA, KENBLUE, MERION, PARK, RUGBY, SOUTH DAKOTA CERTIFIED, WABASH, WARREN'S A-34, MONOPOLY, ADELPHI, AMENLLA BONNIEBLOE, BRISTOL, CHALLENGER, ECLIPSE, MAJESTIC, MIDNIGHT (note: these are only the more common ones used in the western U.S.)

2) COMMON USES

Turf, pasture, hay, wildlife, soil erosion control

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Evasiveness

Kentucky bluegrass is often considered a perennial rhizomatous species introduced from Europe by early settlers (Vinall and Hein 1937). It is a common increaser on disturbed sites in the steppe region (Bates 1935; Burden and Randerson 1972). Kentucky bluegrass is able to colonize microsites in disturbed areas more than species with relatively narrow microsite requirements that are restricted in distribution (Harper et al. 1965). It is not as conspicuous as bluebunch wheatgrass but it can become dominant in the *Festuca - Symphoricarpos* habitat type (Daubenmire 1970). Germination is regulated by temperatures and moisture. A daily flux in soil temperature from 13° to 27°C induces the most germination (Brown 1902). Germination occurs in the autumn, and significant root growth occurs during winter (Hansen and Jaska 1961). The winter root growth gives it an edge over such natives as bluebunch wheatgrass, which grows very little in the winter (Harris 1965). Growth and flowering phenology are similar to that of cheatgrass and bluebunch wheatgrass.

McArthur et al. (1994) states that Kentucky bluegrass and smooth brome are "competitive, persistent, and restrict the entry of native herbs and shrubs into their sward-like stands at the Grand Teton National Park near Jackson Hole, Wyoming. They note that Del Moral (1985), and Golberg and Grass (1988) describe similar findings." McArthur et al. (1994) found Kentucky bluegrass to be present on more of their study areas than any other taxa except common dandelion (*Taraxacum officinale* Weber) (14 out of 16 areas). They found that Kentucky bluegrass, timothy (*Phleum pratense* L.), and smooth brome dominated the meadow area and the severely disturbed sagebrush-grass site.

Bookman (1980) found that Kentucky bluegrass competed well with cheatgrass in southwest Oregon, by it preventing cheatgrass lateral root spread. Reduction in cheatgrass rooting volume was a function of the established Kentucky bluegrass root system which usurped both space and associated resources in the soil matrix. Early establishment of Kentucky bluegrass conveyed an advantage that allowed the capture of a disproportionate share of resources that determined the final position of cheatgrass (Harper 1977). These results are similar to those for orchardgrass in which relative timing of seedling emergence determined the amount of soil resources that seedlings usurp before significant neighbor to neighbor interference occurs (Ross and Harper 1972).

Observations and research findings by Winward (1994) noted that Kentucky bluegrass did not compete with Douglas fir (*Pseudotsuga taxifolia* Britton) once the tree roots were below those of Kentucky bluegrass. He found that Kentucky bluegrass competed very little with pinegrass (*Calamagrostis rubescens* Buckl.) and elk sedge (*Carex geyeri* L.). In contrast it competed with Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass. Kentucky bluegrass did not eliminate either fescue or bluebunch wheatgrass, but was compatible with them (Winward 1994).

Zamora (1994) found that Kentucky bluegrass was unable to compete with elk sedge and pinegrass and other native species on a Douglas and Grand fir site in western Washington at the Centralia Mining Company located 10 miles east of Centralia. Furthermore, he noted that velvetgrass, (*Holcus lanatus* L.), red top (*Agrostis alba* L.), trailing blackberry (*Rubus macropetalus* L.), and mountain ash (*Fraxinus* L.) replaced Kentucky bluegrass stands.

McLean and Tisdale (1971) studied vegetation changes using livestock exclosures and found that after 29 years there were five times the foliage cones of bluebunch wheatgrass and Kentucky bluegrass inside the exclosures as compared with the outside, indicating compatibility between bluebunch and Kentucky bluegrass.

Kenkel et al. (1991) studied "the hypothesis that competition and salinity together play a role in creating vegetation zones in the field." Vegetative species considered were: *P. pratensis, Hordeum jubatum* L., and *Puccinellia nuttalliana*. They reported a "competitive advantage at different salinity levels: *P. pratensis* at the lowest salinity, *H. jubatum* L. at intermediate levels, and *P. nuttalliana* Schult. at highest salinities."

Krueger (1994) and Winward (1994) noted that Kentucky bluegrass cannot tolerate a high water table, but is very aggressive and strongly competes on dry meadow sites in areas receiving 18 to 25 inches of precipitation. They noted as have others (Carlson 1994, Gibbs 1994, Harris 1994, and Harrison 1994) that it withstands grazing pressure from livestock and wildlife. It often dominates and readily competes with native species on disturbed sites. Krueger (1994) found on a dry meadow site at the Hall Ranch near LaGrande, Oregon, that Kentucky bluegrass dominated native species including *Deschampsia* spp. Krueger and Winward (1974) reported that within a livestock enclosure Douglas fir-ninebark (*Physocarpus malvaceus* [Greene] Kuntze) (Daubenmire 1970), elk sedge, pinegrass, blue wildrye (*Elymus glaucus* Beubl) and western needlegrass (*Stipa occidentalis* Thunb.) withstood competition from Kentucky bluegrass. They found that at the livestock-big game exclosure, ninebark and red stem ceanothus (*Ceanothus sanguineu* L.) dominated the site.

Gomm (1974) reported that Kentucky bluegrass is very competitive in western Montana. He found it to spread to several seeded plots after a period of five to nine years. In some instances it "nearly covered" the plots.

3.2) Wildlife Usage

Kentucky bluegrass is heavily grazed (depending on the season, phenological stage and kind of wildlife), by mule deer, elk, antelope, and moose (Carlson 1994, Gibbs 1994, Harris 1994, Harrison 1994, Krueger 1994, Winward 1994). The response of Kentucky bluegrass to grazing by big game (mule deer and elk) on a Douglas fir-ponderosa pine-Kentucky bluegrass community in the Wallowa Mountains of eastern Oregon was observed over a 14-year period by Krueger and Winward (1974). Frequency of Kentucky bluegrass in ungrazed and big-game-only grazed pastures remained 100% indicating no significant loss of stand due to big game use.

Diet preference of bighorn sheep *(Ovis canadensis* Douglas*)* for Kentucky bluegrass was evaluated on a 42-ha exclosure 10 km south of Penticton, British Columbia in a vegetative transition zone between big sagebrush and ponderosa pine *(Pinus ponderosa* Laws). The annual seasonal diet frequency of bighorn sheep for Kentucky bluegrass varied from 2.5 to 4.7 % (comparatively low) in 1977 to 1978, respectively. The selection indices of 2.3 to 3.4 for the same period "were associated with a combination of phenological patterns, plant morphology, environmental site characteristics, and grazing preferences" (Krueger and Winward, 1974).

3.3) Summary

Although some have stated that Kentucky bluegrass is indigenous to the intermountain region of the western United States, early literature states that it was introduced to the native Columbia Basin flora. Researchers have found, on moist and dry meadows with more than 18 inches of annual precipitation, it to be an aggressive spreader and very competitive on adapted sites. Apparent root growth during the winter gives bluegrass a decided advantage over natives that lack such growth. When present as a sward it restricts the entry of native herbs and shrubs. In some instances it competes well with cheatgrass. However, it does not compete with Douglas fir once the roots are below those of bluegrass. Although it may grow compatible with bluebunch wheatgrass and fescue it is unable to compete with elk sedge, pine grass, velvet grass, red top, trailing blackberry and mountain ash (in western Washington). In other instances Kentucky bluegrass may dominate native species such as *Deschampsia* spp. or it may grow as an equal with elk sedge, pinegrass, blue wildrye and western needlegrass on other sites. Thus, the competitive nature of Kentucky bluegrass is highly dependent upon environmental conditions. It withstands grazing under heavy livestock or big game grazing pressure and may dominate by becoming a monoculture under such management conditions. It is highly desired by livestock and a variety of wildlife herbivores.

ORCHARDGRASS

1) TAXONOMY AND ORIGIN

Although numerous taxa have been formally published and variously recognized for orchardgrass within its indigenous Eurasian distribution, virtually all North American authors of floristic manuals have historically opted to include without formal recognition all morphological and cytological variants within one polymorphic species. Piper and Beattie (1901) listed orchardgrass as an escape from cultivation upon the Palouse.

1.1) Scientific Names

Dactylis glomerata C. von Linné, Sp. Pl. ed. 1:71. 1753.

1.2) Other Common Names

cocksfoot

1.3) Cultivar Names

BERBER, COMET, CROWN, HALLMARK, HAWK, INA, JUNO, KAY, LATAR, NAPIER, ORION, PAIUTE, PALESTINE, PENNLATE, POTOMAC, SUMAS, DWARF ORCHARD, AKOROA, BRAGE, POMAR, RIDEAU, S-143
(This is a list of more common orchardgrass cultivars used in the western U.S.)

2) COMMON USES

Pasture, hay, green chop, silage, orchard ground cover

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Orchardgrass is a long-lived, shade-tolerant bunchgrass with good seedling vigor. It readily establishes itself when there is little competition from other plants. Some orchardgrass cultivars are more competitive than others in different Columbia Basin ecosystems. Latar orchardgrass is winterhardy and more competitive in colder areas than Akaroa, which winter-kills east of the Cascade and Sierra Nevada Mountain ranges. Paiute orchardgrass is more competitive than Latar and most other orchardgrass cultivars in lower precipitation areas (SCS, PPMC annual reports and species files).

Elliott and White (1987) noted that orchardgrass competed with Ponderosa pine seedlings for moisture and nitrogen in their study near Flagstaff, Arizona. They felt that pine seedlings utilized ammonium while orchardgrass absorbed nitrate. They further suggested the possibility of a growth reduction of pine seedings due to allelopathy effects, as suggested by Rice (1974, 1979). Powell et al. (1994) found that orchardgrass competed with lodgepole pine (*Pinus contorta* var. *latifolia* Engelm) seedlings in southern British Columbia. The lodgepole pine seedlings decreased with increased orchardgrass seeding rates. The lodgepole pine diameters were decreased more than 38%, while height was reduced to 30%. Clark and McLean (1975) reported that survival, height, and plant mass of 6-month-old lodgepole pine seedings decreased as density or orchardgrass increased. They reported in a later study (Clark and McLean, 1979) that lodgepole pine survival was not affected by density of orchardgrass after four years.

Competition of orchardgrass and seven other grass species, seeded with dalmatian toadflax in cultivated and non-cultivated plots with and without St. Johnswort (*Hypericum scouleri* Hook), was studied by Gates and Robocker (1960) on rangeland located 25 miles north of Spokane, Washington. No grass seedlings survived on the non-cultivated sites because of competition from cheatgrass and annual Lotus. No information was available on what effect the weedy species have on the seeded grasses. The cold, open winter caused extensive grass plant reduction on the cultivated sites. Apparently "seeded grasses had little or no adverse effect on the weedy species."

Borman et al. (1990) studied the potential of orchardgrass and other grass species, including wheatgrasses, to occupy two sites in the foothill ecosystem, Mediterranean/Maritime climatic regime, in southwest Oregon. During the mild 1987 - 1988 winter growing period the absolute biomass of orchardgrass was greater than the wheatgrasses on one site and comparable with all the perennial grasses at another site. During the colder 1988 - 1989 winter the absolute biomass for orchardgrass and wheatgrasses was lower than the previous year. Timing of growth and phenological development was earliest in Berber orchardgrass, followed by Palestine orchardgrass, intermediate wheatgrass and latest in tall wheatgrass. Many of the wheatgrass plants suffered high mortality during 1989. If perennial grasses are to survive with annuals in these areas, they must initiate growth early, continue through the winter, and mature before soil moisture is depleted. Berber orchardgrass best fits this growing regime. Palestine orchardgrass and the wheatgrasses (intermediate and tall) follow in that order.

Zamora (1994) found orchardgrass non-competitive with native species at the Centralia Mining Company in western Washington in a Douglas and Grand fir site. Gomm (1974, 1994) found orchardgrass non-competitive with native plants in western Montana and Wyoming. Other scientists (Carlson 1994, Gibbs 1994, Harris 1994, Krueger 1994, Winward 1994, Ogle 1994, and Harrison 1994) have found orchardgrass to be non-competitive in various areas of the Columbia River Basin.

Krueger (1994) noted at the Hall Ranch, near LaGrande, Oregon, that elk sedge will invade orchardgrass stands. He further noted that orchardgrass can spread and coexist with native species. McArthur et al.(1974) found that orchardgrass is competitive and restricts the entry of native herbs and shrubs when it exists as in a sward.

Chambers' (1989) study focused on: "What effects do seeding density of introduced grasses and fertilization have on establishment and growth of native grasses, forbs, and shrubs?" This study was conducted on a oil drill pad on the north slope of the Uintah Mountains of Utah. It included five introduced species (including intermediate wheatgrass and orchardgrass) and four native grass species. Results showed that "introduced grass standing crop biomass increased with each increase in grass seeding density" while native species showed no differences. Orchardgrass and intermediate wheatgrass ranked second and third respectively in biomass production. Biomass production of slender wheatgrass was slightly less than that of the introduced species.

This study also indicated that "seeded grasses (including Fairway crested wheatgrass, intermediate and tall wheatgrass, and orchardgrass) and forbs showed no negative associations among themselves... In contrast, the non-seeded species show almost as many negative as positive associations among themselves."

3.2) Wildlife Usage

Orchardgrass is highly palatable to mule deer and elk in the early phenological stages. In fact, elk have eliminated orchardgrass seedings by heavy use (Gibbs 1994, Harrison 1994, Pudney 1994). Austin et al. (1994) found that mule deer preferred Paiute orchardgrass in the spring and summer over all other 15 planted grasses in central Utah.

Upland game birds use orchardgrass for cover and nesting and small birds eat its seed (Gibbs 1994, Harrison 1994).

3.3) Summary

Orchardgrass in the Columbia River drainage is somewhat shade tolerant, has good seedling vigor and spreads by seed in open and shaded areas. This bunchgrass is generally considered noninvasive, compatible with native species, and does not outcompete natives in most ecosystems. Although orchardgrass may have little or no adverse effects on weedy species, it reduces the growth of pine seedlings. Nevertheless, after several years, stand survival was not different in lodgepole pine stands established with and without orchardgrass. Orchardgrass does spread under the right conditions, but it frequently coexists with natives and thus increases biodiversity except in those instances when it is purposely established as a pure sward. It is highly palatable to livestock and wildlife herbivores.

REED CANARYGRASS

1) TAXONOMY AND ORIGIN

Although the taxonomy of reed canarygrass, *Phalaris arundinacea* C. von Linné, in North America has been comparatively stable, doubt still exists as to whether this species was part of the indigenous flora prior to European occupation. As with many other apparently circumboreal grasses, such as *Deschampsia caespitosa* (C. von Linné) P. Beauv. or *Festuca* *ovina*, many stands of reed canarygrass are likely indigenous while numerous others have been purposely introduced from European populations. Both Anderson (1961) and Baldini (1993) treated reed canarygrass as a circumboreal species, and Piper and Beattie (1901, 1914) listed this species as native and "common in wet places, often in shallow water."

Recently, Baldini (1993) divided *P. arundinacea* into two species based on ploidy level and inflorescence morphology: *P. rotgesii* (Husnot) Baldini, a diploid ($2n = 2x = 14$) putatively endemic to southern Europe and *P. arundinacea*, a tetraploid ($2n = 2x = 28$) with cosmopolitan distribution. Some herbarium specimens of reed canarygrass from western North America conform morphologically to *P. rotgesii*; however, their chromosome numbers are unknown. Further investigations are needed to assess the reality of the supposedly diagnostic ploidy/morphology correlation employed by Baldini in naming *P. rotgesii*. Additionally, plants with variegated leaf-blades, formally recognized as the variety or form *picta*, are occasionally found among stands of reed canarygrass.

1.1) Scientific Names

Phalaris arundinacea C. von Linné, Sp. Pl. ed. 1:55. 1753.
Phalaris arundinacea C. von Linné var. picta C. von Linné, Sp. Pl. ed. 1:55. 1753.
Phalaris arundinacea C. von Linné f. picta (C. von Linné) Ascherson *et* Graebner, Syn. Mitt. Eur. Fl. 24. 1898.
Phalaris rotgesii (Husnot) Baldini, Webbia 47(1): 13. 1993.

1.2) Other Common Names

Reed grass, ribbon grass, speargrass

1.3) Cultivar Names

AUBURN, CASTOR, FLARE, FRONTIER, GROVE, IOREED, PALATON, RISE, SUPERIOR, VANTAGE, VENTURE

2) COMMON USES

Pasture, hay, stream and channel ditch bank stabilization and other soil conservation practices, water pollution control from sewage effluent

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Zamora (1994) noted that reed canarygrass is a very aggressive rhizomatous grass that persists between the aquatic and upland zones in Washington. Comes (1971) also reported that reed canarygrass is extremely competitive. It occurs on several thousand miles of ditch bank in the Columbia Basin and grows vigorously along the waterline of ditches and to a lesser extent on the drier portion of the bank. Rootlets develop at each node as they contact water or moist soil along banks. It will completely eliminate legumes from a community in two or three years (Bonin and Tomlin 1968; Heath and Hughes 1953). Reed canarygrass has a broad adaptation with large acres in Oregon and Washington. Schoth (1929) claims that most of the reed canarygrass fields in the Pacific region can be traced to a seeding made in 1895 in Coos County, Oregon.

Although the natural habitat of reed canarygrass is poorly drained wet areas, it grows quite well on upland sites. Under its most favorable growth conditions both quackgrass (*Elytrigia repens* [L.] Nevski) and redtop (*Agrostis gigantea* Roth) have difficulty in competing with reed canarygrass. Reed canarygrass is intolerant to shade and gives way to willow (*Salix* sp. L.) red osier dogwood (*Cornus stolonifera* Michx.) and chokecherry (*Prunus virginiana* L.). Sedges (*Carex* sp. L.) and rushes (*Juncus* sp. L.) have replaced reed canarygrass in some areas (Zamora 1994).

3.2) Wildlife Usage

Reed canarygrass is used as a habitat for pheasants and ducks in upland and wetlands, respectively. Small birds eat the seed. Small mammals use it as a habitat in upland areas (Chatterton, 1994; Harrison, 1994).

3.3) Summary

Reed canarygrass is generally a highly aggressive, competitive, persistent and vigorous perennial grass that grows in poorly drained wet areas on stream and canal banks in the drainage of the Columbia River. It usually dominates and grows as a monoculture in the areas where best adapted. Where it is best adapted, even quackgrass and redtop have difficulty competing with it. However, reed canarygrass is intolerant of shade and has been replaced in some instances by sedges, rushes, willow, red osier dogwood, and chokecherry.

TALL WHEATGRASS

1) TAXONOMY

Historically, tall wheatgrass has been treated as "*Agropyron elongatum* (Host) Palisot de Beauvois" in most North American grass treatments. As noted by Dewey (1984), Löve (1984), and Moustakas (1993), true *Agropyron elongatum*, now generally excluded from *Agropyron sensu stricto*, is a diminutive diploid ($2n = 2x = 14$), while the robust grass known as tall wheatgrass is a decaploid (2*n* = 10*x* = 70). Differences in plant stature, spike and spikelet morphology, as well as genomic constitution, warrant the segregation of tall wheatgrass as a distinct species. Generic assignment of tall wheatgrass presently varies among authors depending upon the grouping criteria emphasized. The valid combinations available are listed below.

1.1) Scientific Names

Elymus elongatus (Host) Runemark ssp. *ponticus* (Podpera) Melderis, Bot. J. Linn. Soc. 76:377. 1978.
Elytrigia pontica (Podpera) Holub, Folia Geobot. Phytotax. Praha 8:171. 1973.
Lophopyrum ponticum (Podpera) Á. Löve, Feddes Repert. 95(7/8):489. 1984.
Thinopyrum ponticum (Podpera) Barkworth *et* D.R. Dewey, Great Basin Nat. 43(4):570. 1983, *comb. inval.*; Barkworth *et* D.R. Dewey, Am. J. Bot. 72:772. 1985; Liu *et* Wang, Genome 36:648. 1993, *nomen superfluum*.
Agropyron elongatum auctorum non (Host) Palisot de Beauvois
Elymus elongatus auctorum non (Host) Runemark

1.2) Other Common Names

salt wheatgrass

1.3) Cultivar Names

ALKAR, JOSE, LARGO, ORBIT, PLATTE, TYRELL

2) COMMON USES

Pasture, hay, alkaline or saline soil reclamation, wildlife habitat

3) AFFECTS ON REGIONAL BIODIVERSITY

3.1) Competitive Ability and Invasiveness

Tall wheatgrass is a bunchgrass that spreads by seed. Cook and Harris (1968) found that tall wheatgrass started spring growth the same time as western and beardless wheatgrass but reached its advanced growth stage much slower.

Alkar tall wheatgrass did not persist after 15 years at Lind, Washington. The tall wheatgrass planting was replaced by overseeded species of Sherman big bluegrass and Secar Snake River wheatgrass (Stannard 1994).

Gomm (1994) noted that tall wheatgrass has not spread or competed with native plants after 45 years in Star Valley, Wyoming or in a planting made in Bozeman, Montana. Gibbs (1994) and others (Carlson 1994, Harris 1994, Harrison 1994) found that tall wheatgrass persists for long periods once established on adapted sites in Washington, Oregon, and Idaho. It establishes itself as a strong dominant, and when conditions are right, develops into a monoculture. Douglas et al. (1960) reported that tall wheatgrass established well under the low rainfall conditions at Aberdeen, Idaho, but was short-lived. Borman et al. (1990) found that tall wheatgrass has a high production potential in years of above-average precipitation, but does not persist many years in southwestern Oregon or compete well with Idaho fescue and annuals.

Roundy (1983) noted that tall wheatgrass establishes well on some saline soils but does not persist on dry saline soils. He found, as did Young and Evans (1981), that although tall wheatgrass is more salt tolerant than Basin wildrye or slender wheatgrass it is less drought tolerant. Numerous workers (Gibbs 1994, Carlson 1994, Harrison 1994) have noted that many of the sites where Basin wildrye occurs naturally in the Columbia Basin are too dry for tall wheatgrass.

Roundy (1983) compared Jose tall wheatgrass with Magnar basin wildrye grass and found that Jose germinates more rapidly and had higher seedling emergence and greater density than Magnar on both irrigated and nonirrigated nonsaline and moderately saline plots in Utah. Tall wheatgrass had better emergence through a hard soil crust than Basin wildrye; furthermore, Jose had greater and more rapid root elongation than Magnar (Roundy 1983).

Competition of tall wheatgrass and other grasses with big sagebrush on rangelands near Eureka, Utah, were studied by Cook and Lewis (1963). They observed similar rooting depths and concentrations among the various species. Both grass height and leaf length were less and soil moisture was reduced when sagebrush was a significant component.

Seedling competition of tall wheatgrass and other grass species when grown with dalmatian toadflax (*Linaria dalmatica* [L.] Miller) and St. Johnswort were studied on a rangeland 25 miles north of Spokane, Washington (Gates and Robacker, 1960). The "seeded grasses had little or no adverse effect on the weedy species."

3.2) Wildlife Usage

Tall wheatgrass seeds are eaten by birds and rodents. Its abundant foliage furnishes habitats for nesting and cover of upland game birds. Mule deer use it for cover (Gibbs 1994; Harrison 1994).

3.3) Summary

Tall wheatgrass is a long-lived perennial bunchgrass that may persist for a long time on adapted sites. On less-well-adapted sites, including those exhibiting both salinity and low moisture conditions, it is short-lived unless there is a water table below the dry surface. Generally it does not spread. In the Columbia River drainage it competes well with natives such as Basin wildrye on saline soils, but does not withstand drought as well as Basin wildrye and many other natives. In seedings in Utah, tall wheatgrass has done very well under very droughty conditions. The limiting factor is usually its inability to establish as a seedling under dry conditions. Once established it has a very well developed root system that seeks out deeper water sources than most dryland species on arid sites. It also has a great ability to produce large amounts of foliage on areas that have dryer surfaces and heavy soils (Lower Basin salty areas), but sub-surface water. If conditions are right, it establishes as a dominant and may exist as a monoculture.

APPENDIX I

Interrelated Competitiveness of Species

This appendix contains information of a general nature that in some instances relates to the interrelated competitiveness of introduced to native species that was not included in the abbreviated section of a particular species.

Monsen and Anderson (1993) designed a study "to investigate the longevity of a number of introduced and native grasses (132 accessions) and to evaluate variability in plant longevity among ecotypes." The study site was located on a protected "mountain big sagebrush-bluebunch wheatgrass site in south-central Idaho, Boise National Forest." Introduced grasses studied included tall, pubescent and intermediate wheatgrass, Siberian, Standard and Fairway crested wheatgrass and sheep fescue.

"Of the 132 accessions planted in 1939, 40 survived 10 years. The 40 accessions included 34% of the introductions, 38% of the indigenous species, and 18% of species native to the general area. Thirty two (32) years after establishment only 21 accessions survived, which included 19% of the introductions, 27% of the indigenous species, and 3% of the general native species." "In 1991, 52 years after planting, 14 accessions persisted. Only 15% of the introductions and 15% of the indigenous remained. After 52 years the following introduced grass plant accessions were rated the most successful: intermediate wheatgrass, sulcata sheep fescue, and Fairway crested wheatgrass. "Most ecotypes of intermediate wheatgrass, including pubescent wheatgrass survived for 52 years, but some were less abundant than others. Three ecotypes of sheep fescue failed to survive for 10 years, but one was ranked highly successful. Most ecotypes of intermediate wheatgrass were aggressive, long-lived, and extremely persistent perennials. Ecotypes of crested wheatgrass vary in longevity. Fairway crested wheatgrass is much better adapted to more mesic big sagebrush communities than is Standard crested wheatgrass."

Reclamation success, involving intermediate wheatgrass, Kentucky bluegrass, and orchardgrass on the Wooley Valley phosphate mine in southeastern Idaho was evaluated by J. C. Chambers, R.W. Brown, and B.D. Williams (1994). Fourteen years after spoil and topsoil treatment areas were reseeded to a mixture of native and introduced grasses and legumes, the most abundant species on the reclaimed area included intermediate wheatgrass, orchardgrass, and alfalfa. These researchers indicate that "natural successional processes are not resulting in reclaimed areas that resemble native reference areas on much of the Wooley Valley phosphate mine." The highly competitive introduced species have allowed limited establishment of native species. Alternatively, the site may have been altered such that the natives were no longer adapted.

Owens (1987) studied recruitment of big sagebrush *(A. tridentata)* Nutt. subsp. *tridentata)* at the Tintic Research Station in Utah. Sagebrush survival in crested wheatgrass communities was lower than in native or tall wheatgrass communities. Survival was intermediate in a mixture of crested and tall wheatgrass. Within the grazing cell, sagebrush mortality was higher in the grass community than in the rhizomatous grass stand. "More deaths than expected were found in crested wheatgrass pastures and fewer deaths than expected were found in tall wheatgrass stands and native vegetation. Only 612 plants of the 1053 marked as crested wheatgrass stands survived for the entire study period. In the tall wheatgrass stand, 2418 plants of the original 2691 survived and in the native community, 1856 of the 2147 plants survived." The authors did not note the numbers of new seedlings established during the study period.

"Grasses are one set of invading species that in the aggregate may be sufficiently widespread and effective to alter regional and even global aspects of ecosystem function" (D'Antonio and Vitousek, 1992). In North America Kentucky bluegrass is a common invader of disturbed prairies in Canada. Crested wheatgrass has maintained itself on seeded sites and has spread into nearby shrublands. "Grass invasions can have effects at multiple levels of ecological organization from population to the ecosystem." Crested wheatgrass will draw "down soil moisture more rapidly and to lower levels than its native counterpart bluebunch wheatgrass. Crested wheatgrass has replaced bluebunch wheatgrass in portions of the Great Basin and competes more effectively for water with the dominant native shrub than does bluebunch wheatgrass. The foreign grass, cheatgrass, is more abundant in stands of bluebunch wheatgrass than in stands of crested wheatgrass and this difference may occur because cheatgrass begins root growth at a time when established crested wheatgrass are rapidly drawing down soil water. Crested wheatgrass is an effective competitor for phosphorus with big sagebrush stands and it is more effective at phosphorus extraction from the soil than bluebunch wheatgrass. Crested wheatgrass appears to be able to replace bluebunch wheatgrass in sites dominated by the latter in part because of higher seed output, lower seed predation, and the buildup of a large seedbank by crested wheatgrass.

Owens (1987) stated that the interaction of competition with foreign grasses, fire, and the prevention of succession now represents a substantial global threat to biological diversity on the genetic, population, and species level."

Competition between Fairway crested wheatgrass, intermediate, and tall wheatgrasses and orchardgrass and other species in a pinyon/juniper site near Ephraim, Utah was observed by Davis (1987). "...the establishment (seedling) rate was 0.4 (.2 plants per meter square), 12.4 (7.1 plants per meter square), 0.3 (.16 plants per square meter) for fairway crested, intermediate, and bluebunch wheatgrasses, respectively." Fairway crested wheatgrass was usually dominant and not intermediate wheatgrass. The reason why intermediate wheatgrass did so well on this site was: (1) "..not negatively affected by high densities of bur buttercup, (2) cool climate during establishment which favors intermediate wheatgrass, (3) the site received above normal precipitation during establishment and subsequent observation years, (4) " ... once established, this species (intermediate wheatgrass) is considered to be one of the most aggressive and competitive grasses planted in our area...," species which can become established early and are less affected by fungi that attack seedlings in pre- and post-germination stages.

APPENDIX II

General Wildlife Use of Introduced Taxa

Seeding of introduced grasses and other plants on portions of an area can result in earlier green up in spring, a critical time for most wildlife (Ammann et al. 1973). Such seedlings often provide high-quality plant foods that aid in more rapid recovery of body condition lost in the stressful winter period. Seeded (introduced) species can supply significant amounts of green herbage on many sagebrush winter ranges where native species are either dormant or low in availability. Fall green up of crested wheatgrass may supply palatable and nutritional forage in fall and snow-free periods in winter and extend the availability of the limited amount of browse. Seeding of introduced species on spring-fall range reduced the livestock use of browse species and thus reduced competition with wildlife (Lamb 1966, Vale 1974).

Literature pertaining to wildlife food habits on mid-successional sites indicate that deer, antelope, sage grouse, other birds, and small mammals use seeds and foliage from introduced plants in the west (Urness 1979).

"Seed predation by deer mouse and other rodents has contributed to the failure of several seedings (Howard 1950; Spencer 1954; and Nord 1965). "The deer mouse has been singled out as a major consumer of planted seed (Kverno, 1954, Nelson et al., 1970 and Everett et al., 1978)."

Seeds are an important part of the deer mouse diet, especially in the fall and winter when insects and green vegetation are not available (Fitch 1954; Williams 1959; and Whitaker 1966). Seeds of forbs (Johnson 1961), grasses (Frischknecht 1965), and shrubs (Jameson 1952) are consumed at different times of the year, depending on seed availability and floristic composition. Seed size, odor, and nutrient content play an important role in food preference (Howard and Cole 1967; Lockard and Lockard 1971), but when food is scarce deer mice will take almost any food available. Deer mice are also opportunistic in their feeding habits and readily consume new foods (for example, planted seed) that appear on the site" (Johnson 1961; Everett et al. 1978).

Goebel and Berry (1976) provided information that birds can significantly reduce the applied seed and seeding success in an otherwise potentially successful reseeding (Nelson et. al., 1970). These authors cite "Spencer (1954, 1958, and 1959), who has worked extensively on bird and mammal seed protectants for range and forest seeding, and have concluded that damage by birds, small rodents, and insects is so extensive at times that some failures have resulted."

Goebel and Berry (1976) conducted feeding trials for seed preference by 25 different wild birds in an annual-dominated *Agropyron-Poa* habitat type near Asotin, Washington. Six perennial and two annual species were tested. Based on cafeteria- type feeding stations observed during the spring of 1969 they found that the small- seeded sheep fescue was removed more frequently than larger-seeded species such as intermediate and pubescent wheatgrass. Intermediate wheatgrass was the most highly preferred wheatgrass used in these trials. Results from this study concluded that birds may inhibit improvement of range sites by their use of the seed of various species.

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APPENDIX IV

Personal Contacts Made During Data Gathering and Review of Literature

In order to make the Introduced Forage Grass Report as comprehensive as possible, numerous natural resource research scientists, retired research scientists, plant material specialists and range management field people were contacted. These people represented several experiment and research stations, Universities, and plant material centers. Many of the people were visited at their respective location. The following is a list of people and institutions contacted:

A. People Contacted

Jay Anderson, Idaho State University, Pocatello, Idaho
Kay H. Asay, Research Geneticist, USDA-ARS, Logan, Utah
Jack Carlson, Project Leader SCS, CSU, Portland, Oregon; Fort Collins, Colorado
Jeanne Chambers, U.S.F.S., Reno, Nevada
Dale Darris, Plant Materials Specialists SCS Corvallis, Oregon
Wayne Elmore, Riparian Coordinator, WO, BLM, Prineville, Oregon
Gene Findley, Botanist, Vale District, BLM, Vale, Oregon
Jacy Gibbs, Regional Plant Materials Specialist SCS Portland, Oregon
Fred Gomm, Retired, Range Scientist ARS Logan, Utah
Marshall Haferkamp, Range Scientist, ARS Miles City, Montana
Grant Harris, Retired, Professor of Range Management, Washington State University, Pullman, Washington
Kim Harper, Professor of Range Science, Brigham Young University, Provo, Utah
Larry Holzworth, Plant Materials Specialist, Bozeman, Montana
W. Howard Horton, Range Scientist, USDA-ARS, Logan, Utah
A.C. Hull, Retired, Range Scientist ARS Logan, Utah
Don Hyder, Retired, Range Research Scientist ARS Fort Collins, Colorado
Kendall Johnson, Dept. Head, Range Management, University of Idaho, Moscow, Idaho
Clarence Kelly, Retired, Plant Materials Specialist, Pullman, Washington
Robert Kindschy, Retired, Range Specialist, Vale District, Bureau of Land Management, Vale, Oregon
W.C. Krueger, Department Head OSU, Corvallis, Oregon
Scott Lambert, Plant Materials Specialists SCS, Spokane, Washington
Durrant McArthur, Project Leader and Geneticist Shrub Sciences Laboratory USFS Provo, Utah
Steve Monsen, Botanist, Shrub Sciences Laboratory, Intermountain Experiment Station U.S.F.S. Provo, Utah
Jeff Mosley, Professor of Range Management, University of Idaho, Moscow, Idaho
Pete Nissen, Resource Manager, YTC US Army Yakima, Washington

Dan Ogle, Plant Materials Specialist for Idaho, Utah, and parts of Nevada.
NRCS, Boise, Idaho
Mike Pellant, Green Stripping Coordinator, BLM, Boise, Idaho
Richard Pudney, Area Range Conservationist SCS Yakima, Washington
Ben Roché, Extension Range Specialist Washington State University, Pullman, Washington
Phil Rumple, Rangeland Management Specialist, Vale District, BLM, Vale, Oregon
Ken Sanders, Professor of Range Resources, University of Idaho, Twin Falls, Idaho
Mark Stannard, Plant Materials Center Manager, SCS. Pullman, Washington
Lorin St.John, Asst. Plant Materials Center Manager, Bridger, Montana
Forrest Sneva, Retired, Range Scientist, ARS. Burns, Oregon
Tony Svejcar, Research Leader, ARS Unit Burns, Oregon
Ross Wight, Range Scientist, Northwest Watershed Research ARS, Boise, Idaho
Neil West, Professor of Rangeland Resources, Utah State University, Logan, Utah
Alma Winward, Riparian Specialist, USFS, Ogden, Utah
Gary Young, NRCS Plant Materials Center, Aberdeen, Idaho
Ben Zamora, Professor of Ecology, Washington State University, Pullman, Washington

B. Institutions, Stations, and Centers Contacted

1) Universities:
University of Idaho
Idaho State University
Utah State University
Washington State University
Oregon State University
Brigham Young University

2) Research Stations:
Forage and Range Research ARS Logan, Utah
Intermountain Research Station USFS Ogden, Utah
Shrub Science Laboratory USFS Provo, Utah
Squaw Butte Experiment Station ARS Burns, Oregon

3) SCS Plant Material Centers:
Aberdeen, Idaho
Pullman, Washington
Corvallis, Oregon
Bridger, Montana

C. The following data bases electronically searched using key words that included all scientific and common names of species being reviewed plus approximately 30 additional terms such as competition, invasion, biodiversity ...)
Journal of Range Management (1948-1993)
Dissertation Abstracts
National Agricultural Library - AGRICOLA, BIOSIS
USDA-Forest Service INFO Database

Appendix V

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