Grass Germplasm in the USA: A Status Report

prepared by the

Crop Germplasm Committee for Forage and Turf Grasses

Compiled and edited by R.E. Barker, December 1997

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Committee Membership

Arden A. Baltensperger
Department of Agronomy and Horticulture
Box 3Q
New Mexico State University
Las Cruces, NM 88003
Telephone: 505-646-3138
Fax: Fax: 505-646-6041
abaltens@nmsu.edu

Reed E. Barker, Chair
USDA-ARS-NFSPRC
3450 S.W. Campus Way
Oregon State University
Corvallis, OR 97331-7102
Telephone: 541-750-8736
Fax: 541-750-8750
barkerr@ucs.orst.edu

John D. Berdahl
USDA-ARS
Northern Great Plains Res. Lab.
P. O. Box 459
Mandan, ND 58554
Telephone: 701-667-3004
Fax: 701-667-3054
BERDAHLJ@mandan.ars.usda.gov

Mark A. Bohning, Ex-Officio
USDA-ARS, Natl. Germplasm Res. Lab.
4th Floor, Bldg. 003, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
Telephone: 301-504-6133
Fax: 301-504-5536
mbohning@ars-grin.gov

Vicki Bradley, Ex-Officio
Agronomy Curator
Regional Plant Intro. Sta., P.O. Box 646402
Washington State University
Pullman, WA 99164-6402
Telephone: 509-335-3616, 509-335-1503
Fax: 509-335-6654
w6vb@ars-grin.gov

Leah A. Brilman
Seed Research of Oregon, Inc.
27630 Llewellyn Road
Corvallis, OR 97333
Telephone: 541-758-9115
Fax: 541-752-2065
srofarm@ibm.net

Byron L. Burson
USDA-ARS
Dept. of Soil and Crop Sci.
Texas A&M University
College Station, TX 77843-2474
Telephone: 409-260-9300
Fax: 409-845-0456
b-burson@tamu.edu

Michael D. Casler
Department of Agronomy
University of Wisconsin
1575 Linden Drive
Madison, WI 53706-1597
Telephone: 608-262-9557
Fax: 608-262-5217
mdcasler@facstaff.wisc.edu

Chester L. Dewald
USDA-ARS
Southern Plains Range Res. Sta.
2000 18th Street
Woodward, OK 73801
Telephone: 405-256-7449
Fax: 405-256-1322
A031cwoodwar@attmail.com

Ronny R. Duncan
Dept. of Crop and Soil Sciences
Experiment Station
1109 Experiment Street
Griffin, GA 30223-1797
Telephone: 770-228-7326
Fax: 770-229-3215
rduncan@gaes.griffin.peachnet.edu

James H. Elgin Jr., Ex-Officio
USDA-ARS-NPS
Rm. 326, Bldg. 005, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
Telephone: 301-504-5618
Fax: 301-504-6231
jelgin@asrr.arsusda.gov

M. C. Engelke
Texas A&M University
Research and Extension Center
17360 Coit Road
Dallas, TX 75252
Telephone: 972-231-5362
Fax: 972-952-9299
mengelke@aol.com

Donald J. Floyd
Pickseed West Inc.
P. O. Box 888
Tangent, OR 97389
Telephone: 541-967-0123
Fax: 541-967-1023
pickseed@sprynet.com

Melodee L. Fraser
PureSeed Testing, Inc.
P.O. Box 176
606 N. Main Street
Rolesville, NC 27571
Telephone: 919-556-0146
Fax: 919-556-0174
mlkfraser@aol.com

Wayne W. Hanna
USDA-ARS
Georgia Coastal Plain Exp. Sta.
P.O. Box 748
Tifton, GA 31794
Telephone: 912-386-33177
Fax: 912-391-3701
whanna@tifton.cpes.peachnet.edu

James F. Henson
USDA, NRCS, NPDC
P.O. Box 74490
Baton Rouge, LA 70874-4490
Telephone: 504-775-6280
Fax: 504-775-8883

David R. Huff
116 ASI Bldg.
Agronomy Department
Pennsylvania State University
University Park, PA 16802
Telephone: 814-863-9805
Fax: 814-863-7043
Huff@agronomy.cas.psu.edu

Mark A. Hussey
Soil and Crop Sciences Dept.
Texas A&M University
Room 430, Heep Center
College Station, TX 77843-2474
Telephone: 409-845-8795
Fax: 409-845-0456
MHUSSEY@tamu.edu

Kevin B. Jensen
USDA-ARS
Forage and Range Research Laboratory
Utah State University
Logan, UT 84322-6300
Telephone: 435-797-3099
Fax: 435-797-3075
kevin@cc.usu.edu

Richard C. Johnson, Ex-Officio
USDA-ARS, West Reg. Plant Int. Sta.
59 Johnson Hall, Box 646402
Washington State University
Pullman, WA 99164-6402
Telephone: 509-335-3771
Fax: 509-335-6654
rcjohnson@wsu.edu

Virginia G. Lehman
Lofts Seed, Inc.
315 Edgewater Drive
Lebanon, OR 97355
Telephone: 541-451-3478, 541-451-1847
Fax: 541-451-3478
vlehman@aol.com

Gilbert L. Lovell, Ex-Officio
USDA-ARS Plnt Genetic Res. Con. Unit
University of Georgia
1109 Experiment Street
Griffin, GA 30223-1797
Telephone: 770-228-7255
Fax: 770-229-3324
s9gl@ars-grin.gov

Rick Luhman, Ex-Officio
Iowa State University
Regional Plant Introduction Station
Ames, IA 50011
Telephone: 515-292-6502
Fax: 515-292-6690
nc7rl@ars-grin.gov

James R. McFerson, Ex-Officio
USDA, ARS
Cornell University
Plant Genetic Resources Unit
Geneva, NY 14456-0462
Telephone: 315-787-2244, 315-787-2356
Fax: 315-787-2339
jmcferson@ars-grin.gov

Henry L. Shands, Ex-Officio
USDA-ARS
Rm. 117, Bldg. 005, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
Telephone: 301-504-5059
Fax: 301-504-6699
shands@ars-grin.gov

David A. Sleper
Department of Agronomy
210 Waters Hall
University of Missouri
Columbia, MO 65211
Telephone: 573-882-7320
Fax: 573-882-1467
dsleper@psu.missouri.edu

Allan K. Stoner, Ex-Officio
USDA-ARS, Natl. Germplasm Resources Lab.
Rm. 101, Bldg. 003, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
Telephone: 301-504-6235
Fax: 301-504-5536
ngrlas@ars-grin.gov

Charles M. Taliaferro
Department of Plant and Soil Science
Oklahoma State University
368 Agricultural Hall North
Stillwater, OK 74078-6028
Telephone: 405-744-9627
Fax: 405-744-5269
cmt@soilwater.agr.okstate.edu

Kenneth P. Vogel
USDA-ARS
344 Keim Hall, East Campus
University of Nebraska
Lincoln, NE 68583-0937
Telephone: 402-472-1564
Fax: 402-472-4020
agro012@unlvm.unl.edu

Howard Waterworth, Ex-Officio
USDA, ARS
National Germplasm Resources Lab.
11601 Old Pond Drive
Glenn Dale, MD 20769-9157
Telephone: 301-344-3003, 301-344-3004
Fax: 301-344-3441
pgqohw@ars-grin.gov

Richard L. Wynia
USDA, NRCS
Manhattan Plant Materials Center
3800 South 20th Street
Manhattan, KS 66502-9535
Telephone: 913-539-8761
Fax: 913-539-6928

Additional Contributors to this Status Report

James S. Alderson
USDA-NRCS
101 South Main
Temple, TX 76501-7682

David D. Baltensperger
Panhandle Research and Extension Center
University of Nebraska
Scottsbluff, NE 69361
Telephone: 308-632-1261
Fax: 308-632-1365
agri037@unlvm.unl.edu

Phillip Busey
Research and Education Center
University of Florida
3205 College Ave.
Ft. Lauderdale, FL 33314-7799
Telephone: 305-475-8990
Fax: 305-475-4125
pb@gnv.ifas.ufl.deu

Thomas A. Jones
USDA-ARS
Forage and Range Research Laboratory
Utah State University
Logan, UT 84322-6300
Telephone: 801-797-3082
Fax: 801-797-3075

James C. Read
Texas Agr. Exp. Sta.
17360 Coit Road
Dallas, TX 75252

Terence P. Riordan
Department of Horticulture
377 Plant Science Bldg.
University of Nebraska
Lincoln, NE 68503-0724

Introduction/Summary

There are 1,723 species of grasses representing 275 genera in the USA National Plant Germplasm System (NPGS) that can be used for forage, turf, or conservation purposes. These species account for 28,992 individual accessions taking about 7% of NPGS holdings. Clearly, the grasses are an important part of the NPGS system, and the Crop Germplasm Committee (CGC) plays a vital role in assisting with establishing priorities for these grasses.

Members of the CGC represent most of the major USA programs involved with grass germplasm. A broad representation from Federal and state public institutions and from private companies was maintained on the committee. Each committee member submitted information contained in that portion of the report relating to their area of expertise.

While grasses collectively are very important for forage and turf, most individual species are not considered economically important enough to justify full-scale research programs in and of themselves. The perennial nature and genetic complexity (high polyploids, etc.) of most of the grasses increases the cost of germplasm programs above that of other crop species. Thus, one scientist must spread germplasm activities over several species, and close coordination with other breeders or geneticists is mandatory. Close cooperation with scientists in related disciplines is also necessary so that available research resources are effectively invested. Limited financing of genetic programs in recent years has resulted in loss of public and private breeding programs and reduction to minimum levels of research teams in other areas. Continued loss of support for individual species will result in detrimental loss to the overall grass complex. Most present germplasm and breeding activities maximize efficient use of resources while still maintaining high productivity in their programs.

The committee considered germplasm activities for each species and rated present status of activities as adequate (A) or inadequate (X) (Table 1). Those areas where some work is presently underway, but where further support or monitoring is needed, were indicated by ongoing (O). Each generic group was given a priority rating from 1 to 9, with 1 being the highest priority. Ranking in relation to other groups was not attempted because of differing basis of consideration among the generic groups. Both economic input of the generic group, and the need for increased support was considered in the priority ranking. Narrative discussions are provided for each species, or generic group deemed most by the committee. Other species could be considered, but little, if any germplasm work is being done in those omitted. The narrative discussions for cool- or warm-season groupings are arranged in the report alphabetically by generic name.

Considering grasses as a whole, overall goals for grass germplasm activities listed in priority order include:

1. Make an accurate determination of NPGS holdings by species and eliminate duplication of accessions. Propose new collection expeditions to fill deficiencies.

2. Provide appropriate accession descriptor information from field trials and laboratory evaluations.

3. Develop a NPGS site, unit, or procedures that provide for maintenance of vegetatively propagated grasses.

4. Determine molecular tests that can accurately and completely describe and classify genetic diversity among grass accessions.

5. Make recommendations to NPGS about germplasm increase and preservation, and development of core collections.

Table 1. Germplasm Summary Status for Forage and Turf Grasses

Genus	Priority rating†	Germplasm status¶ Collection	Evaluation	Enhancement	Preservation
COOL-SEASON GRASSES					
Agropyron (crested wheatgrass complex)	3	O	O	O	O
Agrostis	3	X	X	O	X
Bromus	5	A,O	A,O	A,O	A,O
Dactylis (orchardgrass)	1	X	X	O	X
Elymus	7	A	O	O	X
Festuca (tall fescue)	1	O	A	X	X
Festuca (fine fescues)	2	X,O	X	X	X
Leymus (North American)	7	X	X	X	X
Leymus (Eurasian)	2	X	X	O	O
Lolium (for forage)	5	A	A	A	O
Lolium (for turf)	3	X	O	A	A
Pascopyrum	6	A	O	O	O
Phalaris (reed canarygrass)	1	X	X	X	A
Phleum (timothy)	5	X	O	O	O
Poa	2	X	A	X	A
Psathyrostachys	2	X	O	O	O
Pseudoroegneria	5	O	O	O	X
Stipeae	7	X	X	X	X
Thinopyrum	5	A,O	A,O	A,O	A,O
Miscellaneous (*Koeleria, Deschampsia*)	2	X	X	X	X

Germplasm Summary Status for Forage and Turf Grasses (continued)

Genus	Priority rating†	Germplasm status¶ Collection	Evaluation	Enhancement	Preservation
WARM-SEASON GRASSES					
Andropogon	5	A	A	A	A
Buchloe	3	X	O	O	X
Cenchrus	3	X	O	O	A
Cynodon	1	X	X	X	X
Eragrostis	6	A	A	A	A
Eremochloa (centipedegrass)	2	X	O	O	O
Panicum (Kleingrass)	3	X	X	X	X
Panicum (Switchgrass)	1	X,O	X,O	X,O	X,O
Paspalum	2	X	O	O	O
Pennisetum (Pearl Millet) and Wild *Pennisetums*	2	A,X	O,X	X	O
Other millets (*Setaria*, *Echinochloa*, and *Panicum*)	3	X	X	X,O	X
Sorghastrum	4	X	X	X	X
Stenotaphrum	3	X	O	X,O	X,O
Tripsacum	3	X	O	O	A
Zoysia	2	X	X	O	O
Miscellaneous (*Bouteloua, Hemarthria, Digitaria, Sporobolus, Schizachyrium*)	4	X	X	X	X

†Priority rating for genus or generic group, 1=high, 9=low.
¶Status coded by A=adequate, O=work underway, and X=work is needed in this area.

COOL-SEASON GRASSES

Lolium multiflorum
(from www.csdl.tamu.edu/FLORA/image/poacr2ba.htm)

CRESTED WHEATGRASS COMPLEX (*Agropyron* Gaertner)

K.B. Jensen

The crested wheatgrass complex is native to Eurasia and most commonly occurs in southern regions of the former USSR, western Siberia, Peoples Republic of China (PRC), and extends southward to Turkey, the Caucasus, and Iran. Since its successful introduction to North America in 1906 (Dillman, 1946), crested wheatgrass has had more impact on revegetation of western rangelands than any other grass. This widely adapted cool-season perennial consists of a complex of diploid (2n=2x=14), tetraploid (2n=4x=28), and hexaploid (2n=6x=42) species. The diploid form is represented in North America by the cultivar Fairway [*Agropyron cristatum* (L.) Gaertn.]. The most common tetraploids are 'Standard' [*A. desertorum* (Fisch. ex Link) Schult.], and 'Siberian' [*A. fragile* (Roth) Candargy = *A. sibiricum*]. The tetraploids are most prevalent on rangelands in the USA, and the diploids are the most important form in Canada (Asay and Knowles, 1985). New sources of diploid, tetraploid and hexaploid germplasm have recently been reported (Asay et al., 1990, 1995a, 1995b; Dewey and Asay, 1982; Dewey and Hsiao, 1984) and may be instrumental in future breeding efforts.

Based on chromosome pairing relationships in interploidy hybrids, Dewey (1974) concluded that the same basic genome, modified by structural rearrangements, occurred at the three ploidy levels. He advised crested wheatgrass breeders to treat the species in the complex as a single gene pool. Although interspecific crosses are often difficult to make and sterility problems are encountered in hybrid progenies, all possible crosses have been made among the three ploidy levels and several schemes have been devised and tested to effect interploidy genetic transfer (Asay and Dewey, 1983).

Dewey (1969, 1974) obtained pentaploid hybrids from crosses between natural (N4x) and colchicine-induced (C4x) tetraploids and hexaploids (6x). His data indicated that fertile 6x or 4x populations could be derived from crosses among 6x-4x hybrids or from backcrosses with their 6x or 4x parents. Genetic introgression from the higher ploidy levels to the diploid level has been impeded by failure of N4x-2x triploids to produce an adequate number of functional reduced gametes in backcrosses to the 2x parent (Dewey, 1971). Triploids obtained from at least partial C4x parentage were found by Dewey (1977) to produce a higher proportion of functional reduced gametes. He used these C4x-N4x triploids in backcrosses to 2x parents to reverse the previously encountered gene flow.

The most progress from interploidy breeding to date has been achieved at the 4x level. Hybridization schemes involving 6x-2x, 6x-4x, 4x-2x, and C4x-N4x hybrids have shown potential for expanding the genetic resources of 4x breeding populations (Asay and Dewey, 1979; Dewey, 1969, 1971, 1974; Dewey and Pendse, 1968; Knowles, 1955). Plant materials from C4x-N4x crosses have been particularly promising. Tai and Dewey (1966) found that C4x tetraploids were moderately fertile and crossed readily with natural tetraploids. Although the fertility of the F_1 hybrid was variable, average seed set compared favorably with that of the parental lines. Dewey and Pendse's data also indicated that selection for improved fertility would be effective and many of the hybrid clones were substantially more vigorous than the parental species. An improved cultivar, Hycrest, derived from C4x-N4x parentage was released in 1985 (Asay et al., 1985a).

'Douglas' is the first hexaploid (2n=42) cultivar (Asay et al., 1995b) of crested wheatgrass to be released in North America. It was released in 1994. The breeding population was derived from hybrids between an accession from the former USSR (PI 406442) and three accessions from Iran (PIs 401076, 401080, and 401085) and one accession from Turkey (PI 173622). 'Vavilov' Siberian wheatgrass was released in 1994 (Asay et al., 1995a). The initial breeding population consisted of ten plants selected from a genetically broad-based population, with accessions originating from VIR, Stavropol Russia, and Eskisehir Turkey. Selection was based on color retention during the late summer under extreme drought conditions. An improved cultivar of Hycrest, CD-II, was released in 1996 (Asay et al., 1997) based on improved vegetative vigor, absence of purple leaves during the early spring, tolerance to diseases and insects, and leafiness.

Present Germplasm Activities

The majority of the breeding work in the crested wheatgrasses is being done at the USDA-ARS Forage and Range Research Lab at Logan, UT. With the departure of Ian Ray at Mandan, ND and Andrew Kielly at Swift Current, SK, limited breeding work is being conducted at Mandan, Saskatoon and Swift Current, Canada. No commercial breeding work is presently being done with crested wheatgrass. The USDA-NRCS routinely evaluates accessions of several grasses and releases the best accessions as cultivars, but they are not involved in an active hybridization and breeding program on crested wheatgrass. Cultivars of crested wheatgrass are listed in Table 1.

Status of Crop Vulnerability

Most of the early cultivars of crested wheatgrass consisted of unimproved germplasm introductions and represent a relatively narrow genetic base. However, starting in the late 1950s to the present, improved cultivars such as Nordan, Fairway, P-27, Hycrest, Ruff, Ephriam, Vavilov, Douglas, Kirk, and CD-II have been developed with a much larger genetic base than the earlier cultivars of crested wheatgrass.

Recent plant collection trips to the former Soviet Union, Mongolia, and northwestern China have greatly expanded our gene base within the Eurasian Agropyrons (Crested Wheatgrasses), with one exception that being six collections of the diploid *A. mongolicum* originating from Mongolia. This narrow-spiked, crested wheatgrass is one of the diploid progenitors to the widely used tetraploids *A. desertorum* (Standard Crested Wheatgrass) and *A. fragile* (Siberian Wheatgrass) (Asay et al., 1992). GRIN lists 380 accessions of *A. cristatum*. Most of the *A. cristatum* accessions were collected from regions of the former Soviet Union (140), Iran (66), China (33), Turkey (31), and Mongolia (20). *Agropyron desertorum* is represented by 107 accessions in GRIN, of which 98 originated from within regions of the former Soviet Union. There are currently 124 accessions of *A. fragile* (= *A. fragile* ssp. *sibiricum*) in the NPGS and all but four were collected from the former Soviet Union.

Even though recent collection trips to the Eurasian countries, particularly China, have greatly expanded the actual number of crested wheatgrass accessions currently held by the NPGS, there are still many areas that have been restricted and valuable germplasm exists within these regions. Recent introductions of *A. cristatum* from Turkey, Iran and the former Soviet Union have shown excellent promise as an arid turf. The newly released hexaploid cultivar Douglas has a relatively narrow genetic base.

Germplasm Needs and Recommendations

A. **Collection -** Additional collections are needed for all species in areas that have been inaccessible during previous collection trips to China and the former Soviet Union. There is a need for additional collections of the hexaploid *A. cristatum*, diploid *A. mongolicum*, and the spreading fine-leaved turf-type *A. cristatum* in order to expand the germplasm pools. Within unrestricted areas of the former Soviet Union, adequate accessions are available for tetraploids *A. cristatum*, *A. desertorum*, and *A. fragile*, however in other Eurasian countries, many of the accessions are limited to a given region and emphasis should be placed on previously uncollected regions.

B. **Evaluation -** Recently acquired accessions of the crested and Siberian wheatgrasses (1989-94) have been evaluated for the basic descriptor and agronomic traits. Much of this data has been submitted to GRIN or is in the process of being compiled for submission to GRIN. With the exception of Robin Quany (Colorado State retired-terminated) who screened the Agropyron collection for turf potential, there is a need for evaluation of basic descriptors and agronomic traits of accessions entered into NPGS prior to 1989.

C. **Enhancement -** No enhancement or breeding is being done by the private sector. With the decline in personnel working in the enhancement of crested wheatgrasses in the public sector, it is imperative that those continuing enhancement programs receive adequate support to continue this research. The USDA-ARS breeding programs in North Dakota and Utah will provide germplasm for the Northern Great Plains and the Intermountain West, respectively. Research has conclusively shown that significant genotype X environment interactions occur for most characters in crested wheatgrass. For example, cultivars developed for the Northern Great Plains will lose much of their genetic superiority when grown in other areas such as the Intermountain Region.

Excellent opportunities are evident to develop improved germplasm pools and cultivars through interploidy breeding procedures. Recent evidence indicates that substantial genetic progress can be made at the hexaploid level, and that genetic traits can be transferred from hexaploid populations to diploid and tetraploid cultivars. Increased emphasis should be placed on development of cultivars for arid turf to provide plant cover in areas where supplemental water is not possible or feasible.

D. **Preservation -** Efforts should be continued to maintain genetic diversity in the national germplasm banks. Scientists should expand their efforts to preserve germplasm pools generated by their breeding and enhancement programs. Genetic integrity of accessions during seed increase is a major problem in cross-pollinated species such as crested wheatgrass. A possible solution to this problem is to increase seed of several species in the same area. The nurseries could be arranged so that accessions of the same species are not planted in adjacent rows. Most of the pollination would then occur among plants of the same accession within the row. Isolation blocks or controlled crosses could be used to increase seed of particularly valuable accessions.

Table 2. Released cultivars of crested wheatgrass

Cultivar	Year	Agency	Parentage
Fairway	1932	Univ. of Sask.	*A. cristatum* diploid from USSR introduction PI 19536
Nordan	1953	USDA-ARS, North Dak. AES	*A. desertorum* tetraploid from USSR
P-27	1953	USDA-SCS, Idaho AES	*A. fragile* tetraploid from USSR
Summit	1953	Agric. Canada, Sask.	*A. desertorum* tetraploid from USSR
Parkway	1969	Agric. Canada, Sask.	*A. cristatum*, Fairway
Ephraim	1983	USFS, USDA-SCS, Utah Div. of Wildlife Res., and several state AES	Rhizomatous form from Ankara, Turkey
Ruff	198-	USDA-ARS, Nebraska AES	*A. cristatum*, Fairway
Hycrest	1985	USDA-ARS, Utah AES, and USDA-NRCS	Induced tetraploid *A. cristatum* X *A. desertorum*
Kirk	1987	Agriculture Canada, Saskatoon	*A. cristatum*-4x, Standard type
Vavilov	1994	USDA-ARS, Utah AES and USDA-NRCS	*A. fragile* from the U.S.S.R.
Douglas	1994	USDA-ARS, Utah AES and USDA-NRCS	A Turkish *A. cristatum*-6x introduction
CD-II	1996	USDA-ARS, Utah AES and USDA-NRCS	Improved selections from the cultivar Hycrest

BENTGRASSES (*Agrostis* spp.)

L.A. Brilman

Bentgrasses, *Agrostis* species, are traditionally thought of as a high maintenance turfgrass species only suitable for golf course usage. In reality, most bentgrass species are low maintenance grasses that are found in many native pastures, meadows and lawns. The principle species currently planted in this country are creeping bentgrass *A. stolonifera* L. var. *palustris* Huds. (currently accepted and equally utilized names are *A. stolonifera* var. *stolonifera, A. palustris, A. alba* L. var *palustris* (Huds). Pers. *and A. maritima* Lam.), colonial or browntop bentgrass, *A. capillaris* (previously *A. tenuis*), velvet bentgrass, *A. canina* L. var. *canina*, dryland bentgrass or 'Highland' bentgrass, *A. castellana*, and redtop, *A. gigantea* Roth (*A. alba* auct. non L.) .All of these species are presumed introduced into the USA from Europe or Eurasia. Many native species of bentgrass are important forage grasses in the western USA including *A.exarata, A. oregonensis* and *A variabilis.* Other species that occur extensively in collections from open ground, old cemeteries, and old turf sites in much of the USA include *A. hiemalis, A. scabra,* and *A. perennans.* Since little is known of the genomic structures of many of these species the amount of hybridization between the native bentgrasses and the introduced bentgrasses is unknown.

Present Germplasm Activities

There are currently 26 creeping bentgrasses in production or scheduled to be placed into production in the USA. Many of these are recently released varieties and their adaptation and total usage have yet to be established. Some of these varieties were put together quickly and represent no new additions to the total gene bank, just a reselection from current material. For many years the entire market in the USA was represented by one cultivar, Penncross. Some of the newer cultivars represent many years of collection and evaluation, primarily at public institutions, selecting from old golf greens which had been seeded with south German bentgrass, which was a mix of species and ecotypes harvested in Germany. How much of the total diversity of any bentgrass species introduced into the USA is represented in our current cultivars is unknown.

There are currently six colonial bentgrasses available in the USA. Two of these, SR 7100 and Duchess, are reselections from the Dutch variety Bardot, which was developed from Dutch ecotype selections. The variety Tracenta also was developed from Dutch ecotypes. The variety Astoria was developed in 1926 from naturalized material collected in northwestern Oregon. The variety Egmont was developed from material selected from old, low maintenance golf courses in New Zealand. The total range of material available has not been evaluated. Colonial bentgrasses have tremendous potential as a low maintenance fairway and home lawn grass.

There are two varieties of dryland bentgrass available, Highland and Exeter. Both are currently sold as colonial bentgrasses because the species separation was not recognized in the USA until recently. This has led to a great deal of confusion in the literature and in germplasm identification.

There are currently only two cultivars of velvet bentgrass listed, SR 7200 and Kingstown. Kingstown has been out of production for a number of years and stock seed is not available. This species shows significant potential as a low maintenance grass for golf courses and home lawns, but only three programs are working on it.

There are currently three redtops released in the USA, Streaker, Fireball and Barracuda. All are listed as being suitable for low maintenance turf, erosion control and forage production. None of these is extensively grown or marketed.

An *A. idahoensis* cultivar has recently been released by Jacklin Seed Company for use as an overseeding species on dormant warm-season grasses.

There are approximately six public and seven private organizations actively involved in bentgrass collection, evaluation and breeding. Most of this work is concentrated on development of creeping bentgrass, with less work on colonial, velvet, dryland and redtop bentgrasses. Additional public organizations are involved in genetic identification and gene technology in bentgrasses, primarily creeping. Most of this work is concentrated on golf course usage. Much of the germplasm is not generally available but is concentrated in private and public collections of individual breeding programs with various levels of description.
The primary source of this material is old golf courses in the USA and much of it traces back to a few cultivars.

There are currently 297 accessions of 14 species *Agrostis* listed in the GRIN database. Some of these represent historical records with no material available. The greatest number of these are *A. gigantea, A.stolonifera, A. capillaris* and *A. castellana,* with more than 200 of the accessions. The native species show very little collection and evaluation with only 2 *A. scabra* accessions. Preservation of germplasm is difficult because the bentgrasses are cross-pollinated and many of them are very aggressive making vegetative maintenance more difficult.

Status of Crop Vulnerability

There are many serious fungal diseases of bentgrasses that must be controlled by fungicides. These diseases are more serious on closely mowed turf, such as golf course greens and in these situations there are also expectations of perfection by golfers. Bentgrasses are also being used more frequently for golf course fairways and have tremendous potential for home lawns, however, even in these situations the current disease susceptibility can present problems. The climactic areas where bentgrasses are being used has also expanded dramatically. Dollar spot, brown patch, leaf spot, snow molds and *Ophiobolus* patch are the most serious diseases. In all cases better sources of resistance are needed. The same is also true of above-ground feeding insects which must be chemically controlled. Endophytic fungi have proven beneficial in insect control strategies of many cool-season grasses. The bentgrasses are known to have these fungi present in some collected material but usually these are the type that choke off the seedhead preventing seed development. More extensive surveys in centers of diversity need to be performed to identify useful germplasm with nonchoke inducing endophytes for both the European and American species.

In addition, early maturing varieties would improve the economics of seed production. Present varieties of creeping, colonial and velvet bentgrass must all be irrigated extensively to obtain good seed production. Currently, only the dryland bentgrasses can be produced without irrigation.

Germplasm Needs

A. **Collection -** New sources of resistance are needed for all of the fungal pathogens of bentgrass, especially in some of the lesser utilized species. Sources of resistance to foliar insects, including nonchoke inducing endophytes, are needed for all of the turf species. This would involve collections in Europe where our common turf species originate. There is also a need to find germplasm sources with earlier maturity and higher seed yields to produce more competitive varieties. The native species of bentgrasses need to be collected and evaluated for reclamation, turf and forage uses. The extent of their usefulness alone or a germplasm source is unknown.

B. **Evaluation -** Bentgrasses in general are included in two NTEP trials, one for greens and one for fairways. The primary species evaluated is creeping bentgrass, primarily because of a greater number of cultivars and breeding programs, but also since the management practiced at most sites favors creeping bentgrasses when other species are included in the trial. Some cultivars of the other species are not included in these trials because proper evaluations will not be done. This is particularly true of lower maintenance species where the high fertility levels often encourage diseases. No testing is done of bentgrasses at home lawn height of cut or maintenance levels. It is often difficult to properly evaluate germplasm before it is included in a cultivar improvement program because of the higher costs associated with these trials. Due to competition very little cooperative exchange occurs between the current private germplasm collections.

C. **Enhancement -** Only a few programs are orientated at finding specific sources of disease resistance, such as the University of Rhode Island involved in dollar spot resistance in creeping bentgrass and brown patch resistance in colonial bentgrass and brown patch resistance in creeping bentgrass at Mississippi State. The mechanisms of resistance need to be better understood and new molecular techniques utilized to track genes of interest through breeding populations. In addition, we need to more thoroughly examine other species and new germplasms for sources of resistance.

D. **Preservation -** The improvement needed for bentgrass preservation involves better isolation during reproduction of new unique germplasms. In many germplasm collections, it is often difficult to identify the species involved until the plant has been observed for two to three years. Some collected plants appear to be interspecific crosses and often these plants, and others with potentially useful genes, produce little or no viable seed in initial crossing blocks so are eliminated from private collections. Vegetative preservation can take up considerable space and time. Better methods of evaluating and utilizing new sources need to be found.

Recommendations

Currently, bentgrasses are utilized in much lower quantities, but usage is increasing and the species show potential for even greater usage. Much of the current chemicals utilized in turf maintenance are used on bentgrasses, even though the total acreage is small. Finding new germplasm sources to reduce pesticide applications in bentgrasses would be very desirable for the environment.

BROMEGRASS (*Bromus* spp.)

K.P. Vogel

There are approximately 60 species of *Bromus* and about 36 of these species are found in the USA. Smooth bromegrass (*Bromus inermis* Leyss.) is the most important pasture and forage *Bromus*. Other *Bromus* species that are used in hay, pasture, and rangeland seedings are meadow bromegrass (*B. riparius* Rehm.), California bromegrass (*B. carinatus* Hook & Arn.), and mountain bromegrass (*B. marginatus* Nees.), but they are of minor importance in comparison to smooth bromegrass. Several annual bromes or cheatgrasses are serious weeds in western rangelands and in small grain fields in the western USA. Smooth bromegrass and meadow bromegrass are introductions from Eurasia. Smooth bromegrass is grown in most of the states that are north of 35 N Lat, but its principal area of use is in the Midwest, northeast, and in the Intermountain West. In these regions it is one of the primary cool-season grasses that is used in pastures and in hay fields in mixtures with legumes. Statistics are not available on the number of hectares seeded to smooth bromegrass, but it is believed to be the most widely grown cool-season grass in the Midwest and the northeastern states north of 40 N latitude. It also is used extensively in the areas where it is adapted for conservation and roadside plantings.

Present Germplasm Activities

Breeding and germplasm enhancement research on smooth bromegrass is currently being conducted at the University of Wisconsin and the USDA-ARS & University of Nebraska cooperative program. Other smooth bromegrass breeding work is on a limited basis by others. Public breeding and enhancement research is less than one scientific year (SY) in each of the public programs. Breeding work on meadow bromegrass is being conducted in the cooperative program at Lincoln, NE. Current breeding programs are emphasizing breeding for forage yield, forage quality, disease resistance, and seed yield. The USDA-ARS & Nebraska AES program has placed considerable emphasis on screening smooth and meadow bromegrass introductions for forage yield and quality in replicated plots and in synthesizing broad-based populations from the better introductions. Recent research at Wisconsin and Nebraska has demonstrated that there is significant genetic variability among bromegrasses for forage quality traits. Research in Pennsylvania and Iowa has shown that there is also significant genetic variability for resistance to important diseases in bromegrass populations. Research in Iowa has shown that initial seedling vigor can be improved by selection for heavier seeds.

Genetic Vulnerability

Smooth bromegrass is an introduced grass and the germplasm source is Eurasia. Most of the current cultivars are based on germplasm collected from eastern Europe and USSR. Smooth bromegrass can still be collected from native stands in these regions. Smooth bromegrass is cross-pollinated and most of the released cultivars are quite heterogenous. There are cultivars available for most areas of the USA where bromegrass is adapted. There are several hundred smooth bromegrass introductions in the NPGS that are from Eurasia. The genetic vulnerability of smooth bromegrass is considered to be low. Other bromegrasses are used on such a limited basis that it is not possible to assess their genetic vulnerability.

Germplasm Needs

A. **Collection** - The current smooth bromegrass collection in the NPGS is adequate to meet the objectives of current breeding programs. All lines entered into the system prior to 1990 have been evaluated, and the data is being summarized for entry into GRIN. A ploidy level series exists in smooth bromegrass. In 1996 and 1997, the nuclear DNA content which is directly related to ploidy level was determined for all accessions in the germplasm system, and the data has been entered into GRIN. Collection expeditions specifically for smooth bromegrass are not needed at the present time. However, smooth and meadow bromegrasses should be collected by plant explorers whenever wheatgrasses or other species are collected from sites where these bromegrasses occur naturally.

B. **Evaluation** - All the PI lines of smooth and meadow bromegrass have been visually evaluated during the increase at the Plant Introduction Station. All PI lines entered into the system for smooth and meadow bromegrass have been evaluated in replicated nurseries at Lincoln, NE, for forage yield and quality as measured by *in vitro* dry matter digestibility (IVDMD) and protein content. New accessions of bromegrasses will probably be collected during the wheatgrass collection expeditions that are currently being planned. If possible, original seed of these new accessions should be made available to breeders for evaluation.

C. **Enhancement** -

D. **Preservation** - Open-pollinated increase is to be avoided. A suggested method of increase that would maintain the genetic integrity of the accessions is to sib-pollinate the plants of an introduction by bagging panicles and transferring pollen between plants. This method will require additional funds for the labor involved in making the sib-pollinations. The seed should be stored in sealed, airtight containers at low temperatures to maintain seed viability over an extended period of time. This would decrease the need to periodically produce new seed lots.

Recommendations

A. Priority of actions--Research needs to be conducted on effective, low cost methods of increasing bromegrass accessions with minimal genetic contamination. All new accessions need to be evaluated by interested breeders using original seed lots and increased by sib-mating. The ploidy level of new accessions can be determined by flow cytometry at the University of Nebraska.

B. Level of support--The cost of evaluating a set of 40 introductions for an array of agronomic traits, including forage quality in a space-planted trial with four replicates, is about $5000 to $10,000 per year for a three-year evaluation period. One year would be used for establishment and the two following years would be used for evaluating lines. The cost of increasing PI lines by sib-pollination is not known, but it is estimated to be about $50 per PI line assuming 40 to 50 plants per PI line were bagged and sib-mated. If 20 of the 200+ PI lines were renewed every year, the cost per year should be about $500.

ORCHARDGRASS
(*Dactylis glomerata* L.)

M.D. Casler

After tall fescue, orchardgrass is the most widely cultivated and broadly adapted cool-season forage grass in North America. It is frequently grown throughout the northeastern and north central USA and can be found in 45 states (van Santen and Sleper, 1996). Its versatility is demonstrated by its excellent adaptedness to both grazing and conservation cutting.

This species is monotypic, which is highly unusual among forage grasses. There are numerous subspecies, most of which are highly cross-compatible. Subspecies *glomerata*, which is tetraploid (2n=4x=28), is the common cultivated subspecies. Most of the other subspecies are diploid, are generally geographically isolated from each other, and are genetically and phenotypically diverse from each other. Most have been shown to be capable of producing 2n eggs and/or 2n pollen, eliminating ploidy as a crossing barrier. It is relatively simple to transfer germplasm from a diploid subspecies to tetraploid level by 2x-2x, 2x-4x, or 4x-2x crosses (Lumaret, 1988; van Santen and Sleper, 1996).

Heterosis has been shown to be extremely important in orchardgrass. Hybridization between diploid and tetraploid subspecies is an excellent mechanism of utilizing potential heterotic patterns and of incorporating unique diploid germplasm into cultivated germplasm. Because heterosis often derives from combination of complementary dominant genes, interploidy or inter-subspecific heterosis can be captured in cultivated varieties.

Present Germplasm Activities

There is probably more activity on this species than any other cool-season forage grass, except tall fescue. Numerous proprietary cultivars have been released within the last 15 years in the USA. Although public efforts have dwindled to two programs (University of Wisconsin and USDA-ARS, Corvallis, OR) in all of North America, some private efforts have been maintained. Recent results from an effort to develop more broadly adapted germplasm suggest that the fullest yield potential of orchardgrass may only be realized with long-term sustained multi-location efforts. Toward this goal, the two USA programs are currently enlisting collaboration from numerous other sites in the USA, Canada, and Europe. Both public and private resources are largely being devoted toward improvements in forage and seed yield and disease resistance.

Approximately half of the NPGS orchardgrass collection was evaluated in Wisconsin in the 1980s. Eleven selected germplasm pools were created from this evaluation, and these are being tested for regional adaptation under both grazing and hay managements.

Status of Crop Vulnerability

There is probably little risk of genetic vulnerability for orchardgrass. The recent flush of new cultivars with average-to-high seed yield has likely infused some new germplasm into the mainstream of the marketplace. Nearly all cultivars show some susceptibility to various rust pathogens, either in forage or seed production regions. New sources of resistance are needed to ensure that the diverse and dynamic rust pathogens do not overcome current moderate levels of resistance. Most particularly, resistance is needed for stripe rust (*Puccinia striiformis*) in Oregon seed production regions. This pathogen may represent the only serious threat for genetic vulnerability of orchardgrass.

Germplasm Needs

A. **Collection** - The common tetraploid orchardgrass collection currently numbers 1092 accessions from Europe, Asia, Africa, South America, and North America. The collection is very extensive and diverse (Casler, 1991). Until screening and evaluation needs are met, there is little pressing need to add additional common tetraploid accessions to the collection. However, there is a pressing need for additional collection of diploid subspecies. There are only 17 diploid accessions, with some subspecies (e.g., *sinensis*) unrepresented. Diploid accessions currently in the collection were added prior to 1960, so original seed is likely nonviable and increased seed is partly homogenized with the remainder of the (tetraploid) collection.

B. **Evaluation** - Approximately half of the collection has been evaluated, but only for field performance in sward plots (forage yield, rust reaction, and maturity). The remaining half of the collection requires evaluation. The entire collection needs to be evaluated for additional descriptors related to use and adaptation of the collection, e.g., tiller density, stress tolerances (e.g., drought and cold), reaction to various rust pathogens, and leaf morphology, including presence/absence of siliceous dentations.

C. **Enhancement** - Current efforts are probably satisfactory. Current programs are working with broad and diverse germplasm pools, and recent cultivar releases have helped to maintain diversity in the marketplace.

D. **Preservation** - Data to develop a core collection and/or combine phenotypically similar accessions are unavailable. Until such time, individual accessions should be increased in as much isolation as is possible and maintained separately. Diploid accessions should be increased in strict isolation from tetraploid accessions.

Recommendations

Collection of additional diploid accessions, from all subspecies, should be the highest priority. This germplasm is under-represented in the collection. It is rapidly heading toward extinction by replacement with more broadly adapted cultivated tetraploid germplasm (van Santen and Sleper, 1996), and it may have value for future maintenance and improvements in orchardgrass performance, stability, and avoidance of genetic vulnerability.

Evaluate the entire collection to identify possible sources of resistance to stripe rust, in particular, and other rusts important in the forage producing regions. Broad-based resistance in new cultivars is the most stable and durable.

ELYMUS spp.

K.B. Jensen

Species of the genus *Elymus* are the most widely distributed and diverse of the Triticeae grasses. Their native habitat ranges from Europe, Asia, North America, South America, New Zealand, and Australia. The genus comprises both wheat grasses and wildryes. *Elymus* is the largest genus of the perennial Triticeae, with about 150 species with various genome combinations of the S, H, Y, P, and W genomes. The respective base genomes are from the following genera *Pseudoroegneria*, *Hordeum*, of unknown origin, *Agropyron*, and *Australopyrum*, respectively. In recent treatments, (i.e., Revision of the Hitchcock Manual and Flora of North American) the genus *Elytrigia* has been included in the genus *Elymus*. Those species transferred to *Elymus* are *E. repens*, *E. pungens*, *E. pycnantha*, and *E. elongatiformis* with *E. repens* (quackgrass) the only taxon of interest in North America.

Within the genus *Elymus,* most species are small-anthered and self-pollinating, with the exceptions of the *E. lanceolatus* complex and the above *Elytrigia* taxa transferred into *Elymus*. Most *Elymus* taxa tend to be rapid developing and vigorous, but somewhat short-lived. Their use generally has been restricted to roadside reclamation and as fast-growing components of seed mixtures in land restoration projects. Slender wheatgrass (*E. trachycaulus*) is a good example, and 'Primar,' 'Revenue,' 'San Luis,' and 'Pryor' are cultivars used in the western USA for soil conservation. The NRCS released the only Blue wildrye (*E. glaucus*) cultivar Arlington in 1995. Three source identified releases of a mildly rhizomatous Canada wildrye (*E. canadensis*) were made by the NRCS for northern Iowa, central Iowa and southern Iowa. Dahurian wildrye (*E. dahuricus*) is similar to the above taxa in that it is short-lived, however, it produces a large amount of aftermath growth after harvesting and is gaining limited acceptance as a forage grass in North America, particularly Canada. Only two cultivars, James and Arthur, have been released to date by the Agriculture Canada Research Station, Swift Current, SK (Lawrence et al., 1990b). Squirreltail (*E. elymoides*), is very drought tolerant and grows on extremely harsh sites. This species has been shown to compete with cheatgrass during establishment. In 1996, the first commercially available germplasm of Squirreltail, 'Sand Hallow,' was released for its high seed yield and medium to late maturity (Jones et al., 1997)

Thickspike wheatgrass (*E. lanceolatus*) is a long-anthered, cross-pollinating, and highly variable species complex. Many populations are adapted to sandy range sites and are excellent forages. 'Sodar' is a low-growing sod-former that has been used extensively for highway seedings in the Intermountain area. 'Critana', from a northern Montana population, is widely used for minespoil reclamation, and currently is the most popular erosion control grass in western USA for arid sites. Recent thickspike wheatgrass releases include 'Bannock' and 'Schwendimar' by the USDA-NRCS in 1994 and 1995, respectively.

Another form of thickspike wheatgrass is subspecies *wawawai*, which is almost indistinguishable from bluebunch wheatgrass (*Pseudoroegneria spicata*), a dominant, widespread range grass. 'Secar,' originally released as a bluebunch wheatgrass, is actually thickspike wheatgrass. It is a vigorous, productive, drought tolerant bunchgrass. The range of subspecies *wawawai* appears to be limited to the lower Snake River drainage, but field testing has shown it to be adapted to most bluebunch wheatgrass sites. It also appears to compete well with cheatgrass.

The complex of species previously treated in the genus *Elytrigia* are indigenous to Europe and Asia. Some species (*E. pungens* and *E. pycnantha*) are restricted to coastal and interior regions of western Europe. *Elymus repens* is naturally distributed throughout much of Europe and Asia, and is now established in many areas of North America and other temperate regions of the world. Because of its aggressive rhizomatous growth habit, it is often considered to be a troublesome weed. This complex as described by Dewey (1984) consists of about five complex polyploid species. These strongly rhizomatous, long-anthered, and cross-pollinated grasses were previously in traditional *Agropyron* and more recently *Elytrigia*. This complex consists of polyploid species with $2n = 42$ or $2n = 56$ chromosomes. Hexaploids are the most common. *Elymus repens*, the type species, is a segmental autoallohexaploid (S S S S XX) whose S genomes 1 1 2 2 are derived from *Pseudoroegneria* and the X genome is of undetermined origin (Dewey, 1967, 1976). It is an extremely variable species that is partitioned into several subspecies. *Elymus elongatiformis* is a 56-chromosome species that has the full chromosome complement of *E. repens* plus another genome (Dewey, 1980).

Present Germplasm Activities

Research is underway at Logan to develop an awnless Secar by crossing it with awnless forms of thickspike. This should make it much less costly to produce. A long-term project has been initiated to further enhance the *wawawai* subspecies. USDA-NRCS currently holds more than 300 accessions of the above species combined. However, it has no formal program for maintenance of this germplasm, except those lines which are selected for increase and further testing. When a project is completed, seed packets usually are discarded as they lose viability. USDA-ARS at Logan and Pullman maintains the most complete collection of *Elymus* germplasm in the USA, particularly of species from outside North America. Recent trips to PRC have increased Asian holdings of *Elymus*.

Germplasm of *E. repens* has been assembled by the University of Wisconsin at River Falls, and the USDA-ARS at Logan. Some collections are much less rhizomatous than typical *E. repens*. For example, an accession (MH-114-1085) obtained from Erzurum, Turkey consisted of plants that ranged from essentially caespitose to moderately rhizomatous (D.R. Dewey, unpublished). The bunch-type strains were described as a new species *E. hoffmanni* (Jensen and Asay 1996). After three cycles of selection, cultivar release is pending for this slightly spreading improved forage grass under dryland to moderate irrigation pastures (K.H. Asay, unpublished). This accession crosses readily with *E. repens,* and it is evident that genetic factors conditioning the caespitose growth habit can be transferred to strains of *E. repens*.

Elymus repens has been extensively used by the USDA-ARS at Logan, UT, as a parent in interspecific and intergeneric crosses. The most promising hybrid appears to be the *E. repens* X *P. spicata* hybrid. The initial cross was made in 1962 (Dewey, 1967). From a plant breeding point of view, the logical goal was to combine the caespitose growth habit, drought resistance, and forage quality of bluebunch wheatgrass with the persistence, durability, productivity, and salinity tolerance of *E. repens*. However, the F_1 was a major disappointment. It was a pentaploid (35 chromosomes), meiotically irregular, morphologically variable, and in general had poor vegetative vigor and various "offtypes" were common. Because the hybrid was partially fertile, generations were advanced without chromosome doubling (Dewey, 1976).

After eight cycles of selection, a fertile breeding population with relatively good fertility and a stable chromosome number of 2n=42 was obtained (Asay and Hansen II, 1984). Characteristics of both parental species were represented in the population. Evaluation trials indicated that the potentially new cultivar was best adapted to a similar precipitation zone as intermediate wheatgrass (30-45 cm). Two germplasms, designated RS-1 and RS-2, were released in 1981 (Asay and Dewey, 1981). Subsequently in 1989, the RS-hybrid germplasm was released as the cultivar NewHy, which has gained wide acceptance for use as a forage pasture grass on high saline areas and areas receiving between 13-18 inches of annual precipitation (Asay et al., 1991). Present work at Logan is looking at the turf potential of the cultivar NewHy and several other hybrid populations utilizing *E. repens* as one of the parents.

USDA-ARS at Logan, UT, is conducting molecular research on hybrids between the apomictic *E. rectisetus* and sexual *E. scabrus* in an attempt to identify, isolate and clone the gene(s) responsible for apomixis.

Status of Crop Vulnerability

None of the species of *Elymus* are sufficiently vulnerable to pests or diseases to warrant special consideration, nor are any of the species currently threatened or endangered to the point of significantly reducing the value of its germplasm.

Although *E. repens* is considered to be a weedy grass in most temperate regions of the world, it has shown exceptional promise as a parent in wide hybridization programs. In addition, germplasm with the caespitose growth habit is available, and limited observations indicate that caespitose to moderately rhizomatous forms of the species are valuable forage plants.

Germplasm Needs

A. **Collection** - Holdings of Asian *Elymus* should be increased as part of a trip to collect perennial Triticeae. Currently, between ARS Logan and Pullman over 1,000 accessions of 120 to 130 species are on inventory from worldwide representations. Emphasis should be placed on those specific species that we have no accessions currently in the NPGS. Many of these accessions are described from material collected in secluded areas of the former Soviet Union and China.

It is recommended that plant explorations for *E. repens* be made to Europe and Asia in previously closed regions to expand our genetic resources. Germplasm should be useful in intergeneric and interspecific hybridization programs as well as new gene pools to genetically modify the rhizomatous growth form of the species.

B. **Evaluation -** Recently acquired accessions of *Elymus* sp. (1989-95), particularly from regions of the former Soviet Union and China, have been or are being evaluated for the basic descriptor and agronomic traits. Much of this data has been submitted to GRIN or is in the process of being compiled for submission to GRIN. There is a need for evaluation of material collected prior to 1989 and domestic collections.

C. **Enhancement -** Improved, drought tolerance and forage quality and yield will be the emphasis in the Snake River wheatgrass breeding program at Logan, UT. Work will continue with several of the hybrids using *E. repens* as one of the parents for increased salinity tolerance, improved forage yield and quality, and possible use as a semiarid turf.

D. **Preservation -** Efforts should be made to maintain genetic diversity in the national germplasm banks with an emphasis on ensuring that domestic collections held by the NRCS are not lost at the conclusion of their evaluations, but included in the NPGS with selected material being sent to long-term storage.

TALL FESCUE
(*Festuca arundinacea* Schreb.)

D.A. Sleper

Tall fescue is a relatively new forage grass species in the USA. It was first evaluated in the late 1800s and early 1900s, largely because of its greater resistance to oat rust (caused by *Puccinia coronata* Cda.), high herbage yield, and persistence, particularly in comparison with meadow fescue (*F. pratensis* Huds.) (Buckner et al., 1979). 'Kentucky 31,' the major cultivar grown in the USA today, was released in 1943. Kentucky 31 is noted for its ability to grow over a wide range of environmental conditions eastward from Oklahoma and Kansas to the Atlantic Coast. This area is often referred to as the transition zone because it is recognized as the division between successful cultivation of cool- and warm-season grasses (Sleper and West, 1996). Tall fescue is grown on an estimated 14 million ha in the USA. Expanded livestock production in the transition zone would not have been possible without the use of tall fescue, particularly the Kentucky 31 cultivar.

Tall fescue belongs to the Bovinae section of the genus *Festuca* and to the tribe Festuceae. Considerable controversy existed earlier about whether tall fescue and meadow fescue should be classified as two or one species. Later work (Terrell, 1979) concluded that tall fescue was a species by itself.

There is also controversy on the relationships between *Festuca* and *Lolium*. Many crossing experiments have shown a close relationship among four taxa, *F. arundinacea*, *F. pratensis*, *L. perenne* L., and *L. multiflorum* Lam. Gene exchange among these taxa occurs freely and little structural chromosomal differentiation exists. Certain taxonomists have advocated that *Lolium* and *Festuca* be classified as being more closely related than presently accepted. Recent molecular evidence using restriction fragment length polymorphisms (RFLPs) indicated that tall fescue has a close relationship with *F. pratensis*, *F. arundinacea* var. *glaucescens*, and that *F. pratensis* and *L. perenne* had the closest degree of relationship (Xu and Sleper, 1994). Popular opinion at present appears to be that more research is needed before definitive conclusions on genomic relationships can be reached.

Tall fescue is reported to have evolved on both the south and north sides of the Mediterranean Sea. It can be found in its native state in much of Europe, and the Tunisian area of north Africa, and in west and central Asia and Siberia (Borrill et al., 1971; Terrell, 1979).

Like many other wide-ranging species, tall fescue has distinguishable ecogeographic races. The excellent fall growth potential of Tunisian hexaploid accessions, for example, suggests that they might be useful germplasm in a breeding program when crossed with locally adapted tall fescue of European origin. Research by Evans et al. (1973) and Hunt and Sleper (1981) have found meiotic irregularities in hybrids between European and Tunisian accessions. It appears that gene transfer may be effected by repeated backcrossing.

Today, tall fescue is cultivated successfully far from its sources of origin. Tall fescue has been introduced to North and South America, New Zealand, and Australia and in east and south Africa. It is also successfully cultivated in southern Canada, Japan, and Mexico (Sleper and West, 1996).

The allopolyploid nature of tall fescue provides a stimulating challenge in breeding for improved cultivars. The complexity causes difficulties in genetic analysis as allelic variation, genome constitution, and ploidy level all influence phenotypic expression. The allopolyploid series within *Festuca* spp. and their genomic constitution, largely as proposed by Chandrasekharan and Thomas (1971a, 1971b), are presented below. Some other ploidy forms not identified in the Table 3 include *F. gigantea* L. (2n=6x=42 and 2n=4x=28) and *F. rubra* L. (2n=6x=42).

A review on the cytogenetics of tall fescue was presented by Berg et al. (1979). Tall fescue contains cultivated hexaploid and wild tetraploid, octoploid, and decaploid varieties, all founded on a basic chromosome number of x=7. The diploid species *F. pratensis* morphologically resembles *F. arundinacea* and probably has contributed a genome to some polyploid fescues. The phylogenetic relationships among tall fescue and its relatives are incompletely understood. Chandrasekharan and Thomas (1971a, 1971b) proposed that the decaploids contain a *F. pratensis* (P) genome. Recent evidence (Sleper, 1985) indicates that the P genome is not part of the decaploid's genetic constitution. The P genome from hexaploid *F. arundinacea* contains a satellited chromosome that can be recognized at meiosis. This satellited chromosome usually does not pair in hybrids between the 6x and 10x forms of *F. arundinacea*. Therefore, it is suggested that the symbol P be replaced with Q for the decaploids. Fescues have few diploids, resulting in difficulty in analyzing the parentage of the polyploid forms. Low crossability and hybrid infertility occur not only in hybrids between the ploidies, but also between geographic races having the same chromosome number (Hunt and Sleper, 1981; Beuselinck et al., 1983).

Recently the first molecular map of tall fescue was published (Xu, et al., 1995). The map was generated from an F_2 population and contains 108 RFLP markers. The map covers 1274 cM on 19 linkage groups with an average of 5 loci per linkage group and 17.9 cM between loci.

One of the problems facing livestock producers is that about 95% of tall fescue pastures in the USA are infested with an endophytic fungus (*Neotyphodium coenophialum*) (Shelby & Dalrymple, 1987). The presence of the endophyte brings about a number of disorders to grazing ruminants while at the same time it helps the tall fescue plant to be more persistent under adverse environmental conditions (Sleper and West, 1996). When collections of tall fescue seed are made, the endophyte is often present as the fungus is transmitted by seed. There are needs to collect various isolates of the endophyte as studies have shown that different strains of the endophyte can have different responses in different genetic backgrounds of tall fescue (Sleper and West, 1996).

Table 3. Proposed genomic formula of *Festuca* species

Species	Somatic number (2n)	Proposed genomic formula
F. pratensis	14	PP
F. arundinacea var. *glaucenscens*	28	$G_1G_1G_2G_2$
F. mairei	28	$M_1M_1M_2M_2$
F. arundinacea var. *genuina*	42	$PPG_1G_1G_2G_2$
F. arundinacea var. *atlantigena*	56	$G_1G_1G_2G_2M_1M_1M_2M_2$
F. arundinacea var. *letourneuxiana* and *cirtensis*	70	$QQG_1G_1G_2G_2M_1M_1M_2M_2$

Present Germplasm Activities

At the present time, very little activity is occurring in this area. D. A. Sleper brought back tall fescue from Poland in 1985, C.P. West from Morocco in 1992 and West and Sleper again from Morocco, Spain, and France in 1993. Many of these accessions have been entered in the National Plant Germplasm System (NPGS).

Presently, several hundred accessions of [*F. arundinacea* var. *genuine* and *F. pratensis*] are available to plant breeders through the NPGS. Virtually none or very little of the other ploidy forms listed in Table 3 are available to breeders and geneticists in this country. Both the cultivated and noncultivated types are in short supply.

Status of Crop Vulnerability

Tall fescue grew on approximately 16,000 ha in 1940 in the USA and now it has become the predominant cool-season perennial grass, occupying an estimated 14 million ha (Buckner et al., 1979 and Sleper and West, 1996). It is estimated that 90% of the hectarage includes the Kentucky 31 cultivar. This puts the USA tall fescue crop in a very genetically vulnerable situation.

The economic potential of tall fescue in the USA can be placed in perspective by reviewing briefly the natural resource base for agriculture in the USA and the ongoing land use changes. Throughout history there have been differences of opinion regarding land use by agricultural and nonagricultural systems. At present, a very serious conflict has arisen that is associated with increased soil erosion, decreased wildlife habitat, more pressure on recreation space, and threats to the maintenance of diversity of the landscape.

This conflict results partly from economic pressures on our domestic agrarian society and from the necessary role that increased agricultural production is playing in the balance of trade. Both of these factors, and the improved technology developed for grain-crop production, have caused millions of hectares of grasslands in the USA to be plowed for soybean, corn, and grain sorghum production. This problem is presently very extensive, helping to make our nation one which loses tremendous amounts of precious top soil each year. The conversion process has assisted temporarily in increasing productivity and export of food and feed grains but at a high cost of soil erosion (productivity), fewer hectares of grassland for meat and milk production, and increased pressures for agricultural use of soil sites traditionally used for recreation and wildlife.

At present, soil conservation is a national priority, and preservation of recreational space and wildlife habitat are paramount. The land-use practice in the USA of using the best soils for food and feed grains has begun shifting livestock grazing to lesser productive sites. In the long-term, this will decrease animal carrying capacity with resulting loss to meat and milk production unless improved tall fescue cultivars and management systems are developed.

The losses occurring in the livestock industry through shifting land use and the lack of improved cultivars of tall fescue represents a critical problem for farmers in terms of reduced forage yields and increased costs of the operation. The loss is not borne exclusively by farmers as the general public also loses from the standpoint of reduced water quality, problems with sediment deposition, increased probability of flooding, and a lower economic base within the community. It is estimated that 40% of the nation's topsoil has been eroded away in the last 200 years. Utilizing high-productive forages such as tall fescue that are also soil conserving represents one way that these losses on the nation's hillsides can be minimized. However, to have high economic return from tall fescue cultivars, they must be both high yielding and provide for high animal performance, factors that would be addressed by broadening the *Festuca* germplasm base.

Germplasm Needs

A. **Collection -** Additional accessions are needed for all *Festuca* species discussed in this report. With approximately 14 million ha of tall fescue in the nation, the germplasm base is not adequate to ensure future stability for this species in the USA.

   Tall fescue and its related species are also needed for turf. It is expected that more breeding effort will be placed on breeding tall fescue for aesthetic purposes in the future, particularly in the private sector.

B. **Evaluation -** Most of the evaluation of *Festuca* germplasm occurs in the public sector. Most of the private sector is involved in evaluation of tall fescue as a turf species. The evaluation effort appears to be adequate at present, based on the small number of accessions that are presently available.

As we look forward to collecting more accessions in the future, this effort will need to be increased.

C. **Enhancement** - Again, most of the activity for enhancement of germplasm for forage purposes occurs in the public sector with the private sector doing most of the enhancing for turf. It is expected that efforts will need to be increased greatly in this area for both turf and forage if more accessions are collected.

D. **Preservation** - Efforts in this area need to be increased. Most of the unique material is in the hands of plant breeders. More effort is needed to increase the number of new accessions and, therefore, increase the efforts of preservation in the future.

Recommendations

Need for additional improved cultivars of tall fescue in the future is expected. There is an increasing emphasis on the conservation of vast soil resources in the USA and throughout the world. Much of the land that is presently under cultivation with row crops will need to be seeded to forage grasses if progress is to be made in minimizing soil erosion.

As economic conditions improve, the demand for animal products increases. Tall fescue comprises an important part of the diet of livestock. For example, in the state of Missouri alone, farmers produce approximately 2 million feeder calves per year. It is estimated that over 90% of the feed units for the calves comes from forages comprised primarily from tall fescue. Meat, milk, and various other ruminant products provide more than half the total protein in the American diet, and the protein is of high biological value. High yielding tall fescue cultivars will be necessary in the future as consumer preference persists for products of ruminants as sources of food, and at the same time when increasingly higher demands and expectations will be placed on ruminant production from the remaining available land resource.

One of the biggest challenges facing the tall fescue breeder in the future will be to improve forage quality. Large advances have already been made in this important area. It is well recognized that higher quality tall fescue cultivars are needed to improve animal performance.

Forage grass breeders expect to have more tools available as genetic engineering concepts are developed for forage grasses. Many forage grass breeders already have participated in this exciting new area. However, most of our forage grasses, including tall fescue, do not readily lend themselves to *in vitro* techniques, and there may be a tendency to overestimate the value of such techniques. As the future of cultivar development proceeds with tall fescue, the potential is high that these genetic engineering techniques will take their place as yet another supplement to conventional plant breeding approaches. However, if tall fescue breeders are to take advantage of these newer approaches, it is paramount that additional germplasm of all ploidy levels within the *Festuca* genera be collected.

A. Collection--Over the next five years, 2500 additional accessions need to be collected over all species within Festuca. Collections need to be made in North Africa and Europe. The endophytes associated with the seed from the newly collected accessions need to be isolated and categorized according to their reaction in specific host plants.

B. Along with collection efforts, increased emphasis needs to be placed on activities in evaluation, enhancement and preservation.

FESCUES FOR TURF
(*Festuca* spp.)

D.R. Huff

The genus Festuca includes hundreds of species and are endemic to Europe and adjacent regions. Eight of these species are used as turf and are commonly known as tall fescue (*F. arundinacea* Schreb.) and a group of species collectively known as the fine fescues.

Tall fescue is popular as turf in the transition zone because of its excellent drought avoidance from deep roots, its persistence, and its adaptation to a variety of soils. It is commonly infected with the endophyte fungus *Neotyphodium coenophialum* (Morgan-Jones & Grams) Glenn, Bacon & Hanlin.. This endophyte causes health problems for livestock from infected forage but enhances tall fescue's persistence as turf.

The fine fescues are a collection of many species all of which share a close morphological resemblance. Seven of these species used as turf include: strong creeping red fescue (*F. rubra* L. spp. *rubra*), slender creeping red fescue (*F. rubra* L. var. *littoralis* Vasey), chewings fescue [*F. rubra* L. ssp. *fallax (Thuilli .)*

Nyman, hard fescue (*F. brevipila* Tracey), sheep fescue [*F. ovina* L. ssp. *hirtula*a (Hackel ex Travis) Wilkinson], blue fescue (*F. ovina* L. *glauca* Lam.), and hair or fined-leaved sheep fescue (*F. filiformis* Pourret). Extensive variability exists within these species. Fine fescues are shade tolerant and drought resistant. Endophytic fungi (*Epichloe* spp. and *Neotyphodium* spp.) are also known to infect several of the fine fescue species.

Present Germplasm Activities

There are over 100 cultivars and experimental strains of turf-type tall fescue currently being evaluated in the USA under the auspices of the National Turfgrass Evaluation Program (NTEP). For the fine fescues, there are over 60 cultivars and experimental strains currently being evaluated under NTEP. The Germplasm Resource Information Network (GRIN) lists 892 accessions of tall fescue and 538 accession of the various fine fescues. While most of the genetic improvements in tall fescue breeding has occurred in the USA, only about half or less of the fine fescues have resulted from USA collection and breeding efforts. Preservation of germplasm is similar to Kentucky bluegrass but is more difficult because fescues possess a cross-pollinated breeding system.

Status of Crop Vulnerability

Brown patch (*Rhizoctonia solani* Kühn) continues to be a serious disease of tall fescue. Although some improved sources of resistance have been found for this disease, additional improvements are needed. Phythium blight (R. *solani* Kühn) can also be very severe particularly given the higher shoot densities of the newest turf-type cultivars. Severe outbreaks of gray leaf spot [*Pyricularia grisea* (Cooke) Sacc.] has detrimental effects with no reported resistance as of yet. New sources of crown rust and Fusarium snow mold resistance are also needed to counteract the many races of these diseases.

Genetic improvement of fine fescues has lagged behind those of tall fescue. There continues to be great need for improved leaf spot (*Bipolaris* spp. and *Drechslera spp.*) resistance, insect resistance, and heat tolerance in all of the fine fescue species. Red thread [*Laetisaria fuciformis* (McAlpine) Bardsall]and dollar spot (*Sclerotinia homoeocarpa* F. T. Bennett) are also serious diseases on the chewings and creeping fescues. There is a need for a rapid and accurate method of species identification so that improvements in all fine fescue species, most notably sheep fescue, may proceed.

Germplasm Needs

A. **Collection** - New and novel sources of resistance to disease are needed in tall fescue and the fine fescues.

B. **Evaluation** - Adequate.

C. **Enhancement** - There are many breeding programs in progress to incorporate new sources of disease and insect resistance into *Festuca* cultivars, but more research is needed to identify the useful sources of germplasm that possess these improved resistance traits. In the case of the fine fescues, an accurate means of species identification is needed to begin to define primary gene pools among the various germplasm sources.

D. **Preservation** - The improvements needed for *Festuca* species preservation involve better isolation during the seed increase of new and unique germplasm sources.

Recommendations

Because tall fescue is such an economically important turfgrass species throughout the transition zone and the West Coast, a high priority should be placed on finding new sources of disease resistance. With an increasing emphasis on conservation, the environment, and use of low maintenance turf there is also a need for new fine fescue germplasm sources with better heat and disease resistance. However, without the ability to quickly identify species of fine fescues, incorporation of new germplasm into existing breeding programs becomes a long-term endeavor.

EURASIAN *LEYMUS* SPECIES

J.D. Berdahl

Most of the breeding and genetics research on *Leymus* species from Eurasia has been confined to Altai wildrye (*Leymus angustus*). Altai wildrye is widely distributed across Eurasia and is found growing on saline-alkaline valley bottoms. Useful attributes of Altai wildrye include high vegetative vigor of established stands, salt and drought tolerance, persistence, and utility for fall and winter grazing due to upright growth of cured stands. Major constraints to commercial production are poor seedling vigor and low seed yield. The species is adapted to sites with heavy soils and semiarid to arid, temperate to cold climates. Altai wildrye is a segmental autoalloploid (2n = 84) containing the Ns genome from *Psathyrostachys* and the Xm genome of unidentified origin. Octaploid (2n = 56) and other chromosome races are common in Altai wildrye and the related species, *L. karelinii* (Turcz.) Tzvel (Dewey, 1984). Genes promoting bivalent pairing appear to be operating in the high polyploid taxa of *Leymus*.

Other *Leymus* species from Eurasia, namely *L. racemosus*, *L. multicaulis*, *L. chinensis*, and *L. secalinus*, may have potential economic importance and should be evaluated in cooperative field trials at several locations within their probable area of adaptation in North America. *L. multicaulis* has relatively high tolerance to salt affected soils. In addition to forage, rhizomatous Eurasian *Leymus* species such as *L. chinensis* and *L. secalinus* have potential conservation uses, and robust species such as *L. racemosus* have high biomass production with potential industrial uses.

Present Germplasm Activities

Germplasm activities are confined to public agencies. About 0.2 SY by USDA-ARS, Logan, UT, and about 0.1 SY by USDA-NRCS is devoted to research on interspecific hybrids of *Leymus*. The program at Logan has generated a series of interspecific hybrid populations involving *L. angustus, L. cinereus, L. racemosus, L. multicaulis*, and other related species with the Ns and Xm genomes. About 0.2 SY by Agriculture and Agri-Food Canada at Swift Current, SK, is directed toward cultivar development in Altai wildrye, *L. angustus*. The breeding program at Swift Current has emphasized selection for improved seedling vigor and seed yield in *L. angustus* and has resulted in the release of three cultivars: Eejay, Pearl, and Prairieland

Status of Crop Vulnerability

Recent collection expeditions greatly expanded our gene base for *L. angustus*, with GRIN currently listing 218 accessions. The gene base for other Eurasian *Leymus* species and for interspecific hybrids of *Leymus* species are both extremely narrow. GRIN currently lists 26 accessions of *L. chinensis*, 25 of *L. racemosus*, 15 of *L. secalinus*, 8 of *L. multicaulis*, and 6 of *L. karelinii*. Leaf spot disease caused primarily by *Septoria spraguei* (Uecker & J. M. Krupinsky was reported on *L. angustus* and *L. arenarius*, as well as several *Leymus* species indigenous to North America (Krupinsky and Berdahl, 1984). Symptoms on *L. angustus* were severe in more humid parts of the Great Plains when forage was stockpiled for fall and winter grazing.

Germplasm Needs

A. **Collection -** High priority should be placed on expanding the narrow gene base of all Eurasian *Leymus* species other than *L. angustus*. Additional collection of *L. angustus* is needed in unexplored areas, and unique genotypes should continue to be collected. Improved interspecific hybrid populations among *Leymus* species may serve as a basis for exchange for additional acquisition of Eurasian *Leymus* species.

B. **Evaluation -** Recently acquired accessions of *L. angustus* need to be characterized for descriptive and agronomic traits, including leaf spot disease reaction. Some *L. angustus* and *L. karelinii* genotypes have similar plant morphology. Ploidy level of *L. angustus* accessions should be ascertained to verify that all *L. angustus* accessions are classified to the correct species. Development of a core collection of *L. angustus* would be possible when adequate data are available.

C. **Enhancement -** The expanded gene base of *L. angustus* provides increased genetic variability and improves the probability that genetic gains can be made for greater seed yield and seedling vigor, the two most critical traits that are limiting more widespread commercial use of Altai wildrye. Also, improved sources of resistance to leaf spot disease caused by *Septoria spraguei* may be available. The three current cultivars of *Leymus angustus* developed by Agriculture and Agri-Food Canada, Swift Current, SK, were selected from populations that originated from only two accessions. Populations from interspecific crosses among *Leymus* species have outstanding adult-plant vigor, high-seed fertility, and high-nutritional quality. The genetic base should be expanded for the most promising interspecific hybrids.

D. **Preservation** - Current accessions of Eurasian *Leymus* species are on inventory at the Pullman, WA PI station, and some accessions are being maintained in the USA. Living Collection of Perennial Triticeae at Logan, UT. Measures need to be taken to preserve the genetic integrity of existing accessions.

Recommendations

The most critical need for *Leymus* species from Eurasia is collection to broaden the genetic base of species that have high potential economic value for filling specific needs in North America. Another important dimension to *Leymus* species is their ease and suitability for intercrossing to produce novel interspecific hybrids of high potential value. Although the genetic base for *L. angustus* has been greatly expanded, there is still a need to collect in areas that have not been covered by previous expeditions. Existing accessions of *L. angustus* need to be characterized for agronomic and descriptive traits. *Leymus chinensis* and *L. secalinus* are similar in morphology and development to western wheatgrass and are adapted to a similar climate. These species may have traits that are lacking in western wheatgrass. The relatively high salt tolerance of *L. multicaulis* is a valuable trait that may provide opportunities to improve forage production on vast acreages of salt-affected soils.

NORTH AMERICAN SPECIES OF *LEYMUS*

T.A. Jones

North American *Leymus* includes 12-13 species. All are strict allotetraploids (2*n*=28) except *L. cinereus* and *L. salinus* which may also be octoploid (2*n*=56), probably either autoalloploids or segmental alloploids. *Psathyrostachys* is known to be the donor of one genome (**Ns**). *Thinopyrum* is no longer considered to be the origin of the second genome, and it remains unknown (**Xm**). Molecular methods, particularly with cytoplasmic DNA, may reveal the identity of the second genome. *Leymus* chloroplast sequences do not appear to correspond with *Psathyrostachys,* and the cytoplasm was probably inherited from the unknown ancestor. *Leymus mollis* (2*n*=28) is being hybridized with bread wheat in Iceland to develop a perennial cereal grain adapted to subarctic environments.

Species may be rhizomatous or caespitose, and hybrid swarms may occur where tetraploids overlap. Most species have seed dormancy or seedling vigor problems, and the rhizomatous species are generally poor seed producers. *L. mollis, vancouverensis, flavescens, arenicola, innovatus, pacificus,* and *condensatus* are found on sandy sites, often in dune landscapes. These species are rhizomatous except *L. condensatus*. Species found on heavier soils may be either rhizomatous (*L. triticoides, simplex)* or caespitose (*L. hirtiflorus, ambiguus, salinus, cinereus*).

Released varieties include Magnar (8*x*) and Trailhead (4*x*) Basin wildrye (*L. cinereus*), Rio beardless, or creeping, wildrye (*L. triticoides*) (4*x*), and Benson American dunegrass, or beach wildrye (*L. mollis*) (4*x*). Rio and Benson are available only as vegetatively propagated material. 'Shoshone' was originally released as a variety of the North American beardless wildrye, but is now considered a member of *L. multicaulis*, an Old World species. The most significant remaining species are *L. salinus* and *L. condensatus.* Demand for species without released varieties will probably be tied to ecological restoration efforts. Material may be released as prevariety germplasm for this purpose.

Present Germplasm Activities

The USDA-NRCS has evaluated numerous accessions of Basin wildrye, leading to the release of Magnar (Pullman, WA) and Trailhead (Bridger, MT). Rio beardless wildrye was released for alkali sites in the Central Valley of California (Lockeford, CA). Benson American dunegrass was released for coastal erosion control and dune stabilization (Palmer, AK). Current evaluation efforts are centered at Logan, UT (*L. cinereus, salinus*) and Meeker, CO (*L. salinus*).

Current breeding efforts are centered at 1) Logan, UT (USDA-ARS) where *L. cinereus* X *triticoides* populations are being improved for salt tolerance, seedling vigor, seed production, and seed dormancy at the tetraploid and octoploid levels, 2) Lethbridge, AB (Agriculture and Agri-Food Canada) where the objective is to develop *L. cinereus* as a grazing crop by improving its forage quality, and 3) Reykjavik, Iceland (Agricultural Research Institute) where *L. mollis* is being developed as a potential cereal crop.

Status of Crop Vulnerability

Prior to intensive cultivation *L. cinereus* was probably much more frequent in Washington, Alberta, and Saskatchewan than at present. The species as a whole is not threatened because of its wide distribution. Particular attention should be paid to *Leymus* germplasm west of the Sierra Nevada and Cascade Ranges because of extensive urban development.

Germplasm Needs

A. **Collection -** Collection efforts should be targeted at all North American species besides *L. cinereus*. Many of these species have limited distributions or are relatively infrequent.

B. **Evaluation -** *L. cinereus* collections need to be initially evaluated for ploidy, though it appears that a strict demarcation separates octoploids in the Pacific Northwest (northeastern Oregon, northern Idaho, Washington, and British Columbia) from tetraploids to the south and east in both the USAs and Canada. Because of its striking blue foliage, some interest has been expressed in the use of octoploid germplasm for xeric landscaping. *L. triticoides* is utilized for livestock grazing in native pastures but exhibits poor seed production, weak seedling vigor, and high seed dormancy. These are traits of considerable interest if this species is to be domesticated. The two species often hybridize where their distributions overlap.

C. **Enhancement -** Enhancement efforts with *L. mollis, cinereus,* and *triticoides* should continue. *L. cinereus* X *L. triticoides* and *L. mollis* X *Triticum* spp. hybrids are of particular interest. Combining tetraploid and octoploid gene pools of *L. cinereus* and *salinus* by hybridizing chromosome-doubled tetraploids with octoploids may generate desirable germplasm.

D. **Preservation -** Gene bank collections of *Leymus* species are meager, both in the USA and Canada. The only species for which an attempt has been made to preserve a comprehensive germplasm pool is *L. cinereus*. The Western Regional Plant Introduction Station (Pullman, WA) holds 166 North American *Leymus* accessions, 70% of which are 4*x* and 8*x* *L. cinereus* with the remaining being *L. triticoides, innovatus, mollis, salinus, ambiguus,* and *condensatus*. The Plant Gene Resources of Canada (Saskatoon, SK) has less than a dozen North American *Leymus* accessions. A collection of *L. cinereus* accessions native to Alberta and Saskatchewan is held by Agriculture and Agri-Food Canada (Lethbridge, AB).

Recommendations

Collect representative accessions of all North American *Leymus* species and enter them into inventories of the National Plant Germplasm System for preservation and evaluation.

RYEGRASS FOR TURF (*Lolium* spp.)

D.J. Floyd

Ryegrass used for turf encompasses three primary species. They are *Lolium perenne* L., *L. multiflorum* Lam., and *L. hybridum* Hausskn. Common names are perennial, Italian, and hybrid ryegrass, respectively. Of these, perennial ryegrass receives the greatest focus for breeding improvement programs.

The genus is native to Europe, temperate Asia, North Africa, and the north Atlantic islands. All species are diploid (2n = 14). Hybrid, Italian, and perennial ryegrasses are wind pollinated and mostly self-incompatible. Perennial ryegrass has been improved significantly during the past 20 years due to active phenotypic recurrent selection breeding programs. It is popular because of its ability to establish rapidly, as well as being persistent and wear tolerant.

During the last five years, ryegrass seed production has averaged 163M Kg in Oregon. Nearly 40% of this is comprised of perennial ryegrass seed production (extrapolated from Oregon Ryegrass Commission report, 1996). The majority of perennial ryegrass seed production is sold to turfgrass markets. In these markets, it is used as permanent monostands, in blends or seed mixtures, and as a prime autumn overseeding component for dormant warm-season grass turf in southern parts of the USA. Italian and hybrid ryegrasses are primarily used in forage markets. If they enter turf usages, it is for temporary turf covers along with overseeding applications. The use of Italian ryegrass for overseeding has decreased steadily in the last ten years, but a small, stable demand still exists. Several plant breeders have indicated that the development of improved cultivars of hybrid ryegrass for overseeding, is a program for them (Turfgrass Breeder Assn., members, 1996, personal communication).

Present Germplasm Activities

The last perennial ryegrass trial established through the National Turfgrass Evaluation Program (NTEP) included 50 named cultivars (NTEP, 1995). The majority of these cultivars were finalized by private breeding programs in the USA. There is one scientific person year devoted to ryegrass breeding for turf in the public sector of the USA. This is contrasted with twelve in the private sector (Frey, 1996). Two recent germplasm collections have been made; by L.R. Nelson and D. Marshall, plus W.L. Graves and P.J. Cunningham. These collections are being increased for seed to be available for breeders (V.L. Bradely, 1996, personal communication).

Status of Crop Vulnerability

A leading area of genetic vulnerability for turf ryegrasses is in seed production diseases. Stem rust, *Puccinia graminis* Pers. is the most significant problem. For turf applications, improved cold hardiness and the ability to tolerate periods of ice sheet cover are desirable characteristics which are seen of limited occurrence in existing germplasm (Murphy et al., 1995). In addition, limited progress has been attributed to breeding in the area of stable resistance to diseases as Crown rust, *P. coronata* Corda, Red thread, *Laetisaria fuciformis* McAlpine, and Dollar spot, *Sclerotinia homoeocarpa* Bennet (Kenna, 1995). Various snow molds can also be significant problems in conducive environments.

Germplasm Needs

A. **Collection** - For perennial ryegrass to maintain its popularity, new sources of germplasm imparting winterhardiness must be found. There are also needs identified that could take advantage of sources improved for the components of seed yield, darker genetic color, and vegetative/reproductive tiller density. Sources of alleles leading to increased tolerance or resistance to the various diseases cited are continually demanded. A wider genetic base for the common endophyte, *Neotyphodium lolii* Latch, Christiensen, and Samuels, is desired.

B. **Evaluation** - Adequate, i.e. through the NTEP system, primarily.

C. **Enhancement** - Adequate

D. **Preservation** - Adequate

Recommendations

The acreage of usage for ryegrasses throughout the world, and especially in the USA, will continue to be widened. As ryegrasses become demanded in markets traditionally sown to other cool season grasses, it is imperative that germplasm collection and preservation continue. Atypical pest problems are starting and will continue to be important. Thus, new sources of genetic material aimed at alleviating such pests are needed. Collection and preservation of novel endophyte containing sources are further needed. The evaluation of new breeding lines and cultivars in the USA is adequate. However, an increased emphasis on disease screening is desired (Turfgrass Breeders Assn., members, 1996, personal communication).

FORAGE-TYPE RYEGRASSES (*Lolium perenne* L., *L. X hybridum* Hausskn., *L. multiflorum* Lam., and *Festulolium braunii* K.A.)

M.D. Casler and L.R. Nelson

Of the four species listed above, annual (Italian) ryegrass (*L. multiflorum*) is the only important forage species in the USA. It is used primarily for winter grazing in the southern and southeastern USA. There has been a large expansion of hectarage in recent years, into Oklahoma, Arkansas, and Tennessee. This is due to the development of more cold tolerant cultivars. However, with this expanded growing region, the increases in cold tolerance have not been able to keep up with the demand for annual ryegrass adaptation. Thus, there is still a need for additional cold tolerance to improve the range of adaptation of annual ryegrass.

The other three are used on a limited basis in humid areas of the northern USA and eastern Canada. Their high-forage quality and ability to establish rapidly make them ideal for use in various systems of no-till seeding renovation. Their use is primarily as components of pasture seeding mixtures and as frost-seeded crops to thicken existing pasture stands. Despite their current limited use, there is interest among growers and seed sales are gradually increasing every year. There is considerable potential for ryegrass use in pasture systems of the northern USA and eastern Canada. However, its major limitation is lack of adaptation to cold, snowless, and windy winters.

Present Germplasm Activities

There have been numerous breeding programs on annual ryegrass in the USA and an expectedly large number of available cultivars. Most programs have emphasized disease resistance and high yield. However, the number of programs has dwindled in recent years and several positions have been lost to retirement. All told there is less than one SY devoted to annual ryegrasses and 0.05 SY devoted to the more perennial species in these genera. Emphasis on the annuals is on greater cold tolerance and disease resistance, while that on the perennials is on selection for persistence and vigor under frequent cutting or grazing. Selection for field survival has increased survival and freezing tolerance (Novy et al., 1995; Casler et al., 1997).

Both the annual and perennial ryegrass collections have been evaluated (Casler 1995; L.R. Nelson, 1996, personal communication). The perennial evaluation emphasized the need for additional winterhardy germplasm, although this may effectively come from introduced cultivars derived from the numerous European breeding programs.

Status of Crop Vulnerability

This is probably not an issue in this species. Germplasm sources available to plant breeders, either through germplasm exchanges or the NPGS are numerous and diverse. Crown rust (*Puccinia coronata* Corda), and possibly stem rust in Oregon (*P. graminis*) may be the only potential pests in the USA that might cause some concern for genetic vulnerability. There are moderate levels of resistance to both rusts in many cultivars, but no sources of high resistance.

Germplasm Needs

A. **Collection** - The recent evaluation of the perennial ryegrass collection indicated that sources of more winterhardy germplasm should be the highest priority for additional collection. Ecogeographic targeting should be for severe winter conditions with inconsistent and/or little snow cover for insulation. Examples might include eastern Europe and mid-altitudes of Switzerland and Italy. Commercial cultivars may also be a means of introducing this variation into the NPGS collection.

B. **Evaluation** - With the completion of both the annual and perennial ryegrass evaluations, there is little need for evaluation at this time. However, there is a need to determine the potential advantages or disadvantages of the fungal endophyte (*Neotyphodium lolii*), which is present in many accessions of these species.

C. **Enhancement** - The greatest need in the northern USA is for continued improvement of freezing tolerance and persistence.

D. **Preservation** - Individual accessions should continue to be maintained and increased in as much isolation as possible.

Recommendations

Develop a core collection of each of the main species, annual and perennial ryegrasses. Develop a protocol by which the main focus of increase and germplasm maintenance is on the core subset of each collection. The great activity and saturation of germplasm and breeding research throughout Europe will likely outweigh most germplasm collection efforts that NPGS could mount. The remainder of the collections should be maintained, but with less rigor than the core subsets. The main focus of USA efforts on this species should be enhancement of existing germplasm and incorporation of elite European material.

WESTERN WHEATGRASS [*Pascopyrum smithii* (Rybd.) Löve]

J.D. Berdahl

Western wheatgrass is an important native grass to the northern USA and to the Canadian Prairie Provinces. It is a dominant or codominant species in the mixed grass and shortgrass prairies. It can be found as far south as the Texas panhandle and as far north as central Alaska.

Cytogenetically, western wheatgrass is an octoploid (2n=8x=56) species. Dewey (1975) reported that it probably originated through hybridization of the tetraploid species thickspike wheatgrass [*Elymus lanceolatus* (Scribn. & Smith) Gould] and beardless wildrye [*Leymus triticoides* (Buckl.) Pilger] or closely related taxa. Meiotically it behaves similar to a diploid, but the complex genetics of an allooctoploid hinders genetic gain from selection.

Because it is native to North America, cultivars are in demand for inclusion in seed mixtures required for various land reclamation projects, roadside revegetation, rangeland renovation, and plantings for wildlife. Forage quality of western wheatgrass is variable, but populations with improved nutritive quality have been selected. The species is well accepted for grazing and hay. Western wheatgrass is moderately tolerant of salt-affected soils. Seeds germinate nonuniformly, but adequate stands are usually attained in two or three years. This rhizomatous species spreads at a moderate rate, and stands are persistent over time. Seed dormancy appears to be present in most available germplasm, and this characteristic could be altered through selection and breeding.

Present Germplasm Activities

Two collections in North America resulted in breeding populations that had a relatively wide genetic base. Johnston et al. (1975) collected open-pollinated seed from 462 selections in southern Alberta and Saskatchewan, and Barker et al. (1983) collected 5140 vegetatively propagated genotypes from 1028 sites in western North and South Dakota. The cultivar Walsh was selected from the Canadian collection, and the Dakotas collection has undergone two cycles of recurrent phenotypic selection for plant vigor, rhizomatous spread, density of foliage cover, and seed yield. Four hundred selected plants from cycle 1 of the Dakotas collection were intermated, and 5 g of seed from each parent were bulked to produce a germplasm release, ND-WWG931 (Barker et al., 1995). In addition, OP seed was harvested from 30 parents with contrasting phenotypes from cycle 0 of the Dakotas collection and entered into the NPGS. At present, OP progenies from 240 selections tracing to the Dakotas and Canadian collections are being tested for forage yield and nutritive quality traits at Mandan, ND, and several synthetic populations will be developed. The Canadian collection was evaluated at Mandan, ND, and 5 g OP seed from 234 plants selected from cycle 0 were bulked to produce a second germplasm release, ND-WWG932 (Barker et al., 1995). Available cultivars consist of Walsh from the Canadian collection, Rodan originating in North Dakota, Rosana in Montana, Flintlock in Kansas and Nebraska, Arriba in Colorado, and Barton in Kansas. Little or no recurrent selection was used in development of current cultivars.

At present, breeding activities on western wheatgrass consist of 0.1 SY by USDA-ARS at Mandan, ND, plus limited activities by USDA-ARS at Logan, UT, and by Agriculture and Agri-Food Canada at Swift Current, SK. Recently, private seed producers have been required by some agencies and institutions to supply seed of "source-identified ecotypes" of western wheatgrass and other indigenous species in place of cultivars for use in revegetation of specified disturbed land. This requirement is not based on scientific data. Collection of source-identified ecotypes by people with little or no training in plant breeding and genetics may result in expenditure of considerable time and resources to produce germplasm that is inferior to current cultivars.

Status of Crop Vulnerability

A total of 50 western wheatgrass accessions (44 from the USA and 6 from Canada) are listed by GRIN. These accessions provide a representative sample of the indigenous germplasm in the Northern Great Plains. Because western wheatgrass is a native grass, vulnerability has been considered to be negligible. It has been assumed that sufficient diversity is present in natural populations to prevent genetic disasters. Western wheatgrass in natural populations usually is associated with other plant species, while cultivars and source identified ecotypes are often sown in monoculture. Evaluation of germplasm for resistance to stem rust, leaf-spot diseases, and root-rot diseases has been limited. Incidence and severity of these diseases have been high on monocultures of western wheatgrass at Mandan, ND, when environmental conditions favored disease development. Sources of resistance to these diseases have not been identified. Genetic vulnerability could be reduced by screening current genetic holdings for resistance to these diseases and developing resistant sources.

Germplasm Needs and Recommendations

A. **Collection** - No further systematic collection of western wheatgrass is needed in the Northern Great

Plains, but it should be collected in association with domestic expeditions for other species, particularly in fringe areas of its adaptation. Systematic collections of the parental species and closely related SH and NsXm species should be initiated.

B. **Evaluation** - Cooperative studies are needed to document the range of adaptation and genotype X environment interactions for existing cultivars and germplasms. Documentation of genetic variability and genetic potential of ND-WWG931 and ND-WWG932 germplasms developed from the two major collections is inadequate.

C. **Enhancement** - No private and very few public breeding programs exist to utilize and enhance existing germplasm. Recurrent selection efforts by ARS at Mandan, ND, should be continued to improve seed yield, forage quality, disease resistance, and reduce seed dormancy. Cooperative testing of germplasm at other locations is needed. Research by ARS at Logan, UT, on parental species and closely related taxa of western wheatgrass should be expanded with the objective of synthesizing improved western wheatgrass through intergeneric hybridization of elite germplasm from parental species.

D. **Preservation** - Current accessions and germplasms of western wheatgrass in the NPGS provide a representative sample of genetic variation across the Northern Great Plains region. Measures must be taken to preserve the genetic integrity of existing accessions. Natural populations of western wheatgrass provide additional sources of genetic diversity.

REED CANARYGRASS (*Phalaris arundinacea* L.)

M.D. Casler

Reed canarygrass is the highest yielding cool-season hay and pasture grass under most conditions found in the upper midwestern USA. It is broadly adapted from the most droughty soils and slopes to the most persistently wet, high-organic-matter bottomland. These traits also give this species the best potential among cool-season grasses as a biofuel crop.

Recent changes in the dairy industry of the north central and northeastern USA favor management-intensive grazing on many farms. Because these systems are grass-based, there is considerable interest on the part of dairy farmers to diversify and improve their grass pastures. Interest in reed canarygrass has increased within the last five years, following its favorable showing in on-farm grazing trials conducted in Wisconsin.

It has some severe limitations, chief among them is its propensity to shatter seed prior to physiological maturity. This is caused by precocious formation of an abcission layer near the top of the rachilla. In *P. aquatica*, a close and cross-compatible relative, a group of three or four genes has been found that cause the rachilla to remain intact during seed ripening. The CSIRO program at Canberra, Australia, has attempted to transfer these genes to reed canarygrass through F1 hybrids and one backcross to reed canarygrass. Despite intense selection for the intact rachilla trait and the reed canarygrass phenotype, not one of 1000 BC1 progeny survived with winter of 1995/96 in southern Wisconsin. This suggested that the reed canarygrass adaptation phenotype had not been recovered sufficiently.

The only other major limitation is its slow rate of seedling development and establishment. There is no known source of genetic variation for this trait.

Present Germplasm Activities

At present, there is only one program with activity on this species (Wisconsin). Emphasis is on selection for persistence and vigor under frequent cutting or grazing. Attempts will also be made to improve seedling vigor.

This species may have potential as a biofuel crop, because of its superior persistence, high yield, and high fiber concentration. Such a usage would require a complete evaluation of the entire collection and most breeding stocks, to reconsider the value of plants with moderate-to-high levels of gramine and/or with tryptamines or ß-carbolines.

Status of Crop Vulnerability

Among all cultivated cool-season forage grasses, we are at greatest risk of genetic vulnerability with this species. With the discovery in the 1970s of four families of alkaloids in reed canarygrass (gramine, hordenine, tryptamines, and ß-carbolines) and their role in regulating animal palatability, intake, health, and weight gain, all efforts have focused on this issue. Because the latter two alkaloids can cause severe health problems and reduce weight gains, all new cultivars have been based on tryptamine- and ß-carboline-free clones. In addition, most breeding programs have attempted to reduce the concentration of gramine and/or hordenine.

Because reed canarygrass is used primarily as a pasture grass and alkaloid concentration and type is an important issue for grazing animals, virtually the entire market for this species has been reduced to the only five cultivars without tryptamines and ß-carbolines: Bellevue, Palaton, Rival, Vantage, and Venture. It is unlikely that any other cultivars are still being produced or marketed (Carlson et al., 1996). Furthermore, these five cultivars essentially trace to only two pedigrees: Palaton, Vantage, and Venture to clones selected from naturalized stands in Iowa and Bellevue and Rival to selections from Canadian collections.

Reed canarygrass is sensitive to some potentially devastating pests, such as frit fly (*Oscinella frit*) and leaf blight (*Septoria* spp.). With all new hectarage planted to one of two pedigrees, there is an element of danger typically not present for highly heterozygous forage crops. A single mutation in one of the above pests or another pest not normally highly virulent on reed canarygrass might lead to wide-scale genetic vulnerability.

Germplasm Needs

A. **Collection -** The greatest needs are for a source of resistance to seed shattering and for improved seedling vigor. New explorations for this species should focus on these two traits. With only 114 accessions, it is doubtful that these traits can be found within the existing collection. Among the cool-season grasses adapted to the humid zone, this is the most agriculturally important species with the smallest collection.

B. **Evaluation -** The entire collection should be evaluated for alkaloid type and concentration. Core collections should be made based on alkaloid information. There are probably too few accessions to use classical morphological traits to subdivide the collection into a core subset. Very little effort or no effort has been expended to systematically evaluate this collection. This is an extremely high priority.

C. **Enhancement -** This species is probably worth more than the 0.02 SY that are being expended on selection and breeding. However, additional efforts will require interest/funding on the part of other scientists.

D. **Preservation -** Individual accessions should continue to be maintained and increased in as much isolation as possible.

Recommendations

Evaluation of the existing accessions for alkaloid type and quantity is the highest priority. Second priority is continued collection of reed canarygrass in wild and naturalized stands, searching for plants that might have superior levels of seed retention and/or seedling vigor.

TIMOTHY (*Phleum* spp.)

M.D. Casler and L.A. Brilman

Timothy is adapted to cool, humid environments in the northern USA and eastern Canada. It is the most important and popular cool-season forage grass in the northeastern USA and eastern Canada. It can be used either for grazing or conservation cutting. It is highly winterhardy and high in forage quality (Berg et al., 1996). It also is increasing in popularity for use as a turfgrass.

The major drawbacks of timothy are: (1) its relative intolerance of heat, (2) its shallow root system that causes poor drought tolerance, and (3) its lack of persistence under a frequent harvesting system, particularly with a low cutting height (Berg et al., 1996).

Phleum bertolonii DC. (P. *pratense* L. *nodosum* L.) or P. *nodosum* L.), turf timothy, is a diploid with 14 chromosomes that is occasionally considered a subspecies of P.*pratense*, a hexaploid species. Turf timothy is a more slender species with a large number of strains, from prostrate types that spread by creeping stolons to very erect types. This species is native to Europe, found from Scandinavia to Portugal and the Balkans, on a wide variety of soils. Due to its compact growth habit, it has been used as a turfgrass in Europe. Additional species of timothy that need further exploration include P. *apinum*, alpine timothy, which occurs from the Arctic regions southward on the mountains of Europe, Asia and America, as far south as the Andes. This is a tetraploid species with short creeping rhizomes. P. *montanum* is another species native to the region of Greece and the Balkan states which has received little attention.

Present Germplasm Activities

In the USA, there are currently only two forage breeding programs on timothy, located in Wisconsin and Indiana. There has been only one cultivar released in the USA since 1971. There was no activity in the USA between 1985 and 1991. Current activities focus on improvement of stress tolerance (mainly heat and drought), forage yield, and disease resistance.

Status of Crop Vulnerability

Although there are numerous cultivars on the market, deriving from diverse breeding programs (USA, Canada, and Europe), most of the market share comes from a relatively small number of old public cultivars and recent proprietary cultivars. Field trials of cultivars have shown little benefit of new vs. old cultivars. Therefore, pest resistance of the old cultivars seems to be highly durable. Genetic vulnerability does not seem to be a concern in timothy for forage at this time.

Very few accessions of any of the species used for turf exist in the GRIN collection. These species appear to primarily have come into the collection as incidental plants from other collections. Of the ten accessions of P. *bertononii* listed, nine are from exchanges with Spain, 1 is from Turkey and one is a cultivar. In the Nordic Gene Bank (NGB) 90 accessions are listed, although some are repeats held at more than one location. Most of the cultivars listed are from Norway, Sweden, Finland and Denmark, but few wild accessions come from these countries. Most of the wild/semiwild material is from Germany with a few plants from France, Poland and Italy. The wide usefulness and geographic range of the species is poorly represented. P. *alpinum* in GRIN has only five accession, two from a collection trip in 1995 in the Caucasus, one each from Iran and Canada and one unknown from 1956. In the NGB, there are 36 accessions, primarily from Greece, with the UK, Sweden, and Italy also represented. P. *montaanum* is represented by only nine accessions, most from the 1960s.

Germplasm Needs

A. **Collection -** Although there are 490 timothy accessions used for forage in the collection, only 11 come from Sweden, one from Finland, four from Denmark and none from Norway. This part of the world is most lacking in the NPGS collection. It is an area to which timothy is highly adapted, with climatic zones similar to large parts of Canada and Alaska. Timothy is one of the best-adapted grasses for hay production in Alaska but there is a need for greater persistence at higher latitudes. Additional collection in naturalized stands and germplasm exchanges with the Scandinavian Gene Bank and/or breeding programs would greatly benefit the broad utilization of the USDA timothy collection. There is a large amount of ecotypic variation among naturalized stands and within breeding programs of timothy in Scandinavia (Jönsson et al., 1991). Domestic collections have been made in Iowa, Minnesota, and Wisconsin, of hayfield remnants from cemeteries, lawns, and golf courses in an attempt to find germplasm tolerant of frequent cutting. These clonal collections are being assembled for seed production in 1998 or 1999. *P. bertolonii* is represented by only ten accessions. Because this species has been used as a turfgrass in Europe, some effort should be made to expand the collection of this species.

   Many of the primary areas of diversity of species used for turf are lacking in the collection. These species have valuable attributes that need to be explored further, such as growing in difficult soils, arid environments and possessing stolons and rhizomes. Until more extensive collections are made, the value for turf, forage or reclamation uses cannot be evaluated.

B. **Evaluation -** Currently, 490 accessions of the *Phleum* collection are being evaluated in Wisconsin. Traits include morphological and seed traits, vigor, and forage quality. From this data, a core collection will be defined and made available through GRIN. Additional evaluation should be dependent on additional needs that may arise in the future.

   Most *Phleum* species have not been evaluated for turf because primarily only cultivars from Nordic countries have ever been available for trials. These would not be adapted to the Mid-Atlantic area so development has not been pursued. Other accessions may have greater utility and these species may be better suited to other regions.

C. **Enhancement -** Selections will be made from the Wisconsin evaluation. The breeding programs in Wisconsin and Indiana will likely continue for a number of years, possibly utilizing materials identified from the 490 accessions evaluated in Wisconsin.

There are presently no enhancement programs in the USA on *Phleum* for turf and those in Europe are small.

D. **Preservation -** Individual accessions should continue to be maintained and increased in as much isolation as possible.

Recommendations

The highest priority is additional collection from northern Europe, mainly Scandinavia, but including northeastern Europe (Germany, Poland, and Russia). Species used for turf could be found in central and southern Europe. The second priority should be additional collection of *P. bertolonii* from central and southern Europe. In both cases, the first course of action should be for NPGS personnel to inquire of possible germplasm exchanges. Should this approach fail, plant exploration should be a high priority. Additional needs are more market regulated and pale in comparison to the above two needs.

BLUEGRASSES (*Poa pratensis* L. and *Poa* spp.)

D.R. Huff

Poa is a diverse genus of widely adapted, cool-season grasses containing approximately 300 species, most of which are palatable and nutritious as forage and several of which are important as turf. Kentucky bluegrass (*Poa pratensis* L.), the agronomic representative species of the genus, is extensively cultivated as forage, as a turfgrass, and for conservation purposes protecting against soil erosion. Characteristics that make Kentucky bluegrass agronomically important include its rhizomatous sod forming ability and its wide adaptability. The facultative apomictic breeding system of Kentucky bluegrass results in asexually produced seed progeny that are uniform and stable but does not allow for genetic enhancement unless special hybridization techniques are used, and even then only a limited number of new hybrid creations are likely to be produced. The center of origin of *Poa* is considered to be Eurasia although it has long been suggested that certain strains of Kentucky bluegrass may be native to northern and western North America and to the intermountain regions of the Rocky Mountains.

Improved cultivars of Rough bluegrass (*P. trivialis* L.) have been developed for use as turf in shady landscape areas and for overseeding dormant warm-season turfgrasses. Cultivars of Canada bluegrass (*P. compressa* L.) are sold and cultivated for pastures on nutrient-poor or thin soils in parts of northeastern USA. Fowl bluegrass (*P. palustris* L.) has been used in seed mixtures for low-lying meadows and pastures.

Species not commercially sold but nonetheless important include the following: Texas bluegrass (*P. arachnifera* Torr.) used as native winter pasture and occasionally as turf in parts of Texas and Oklahoma, bulbous bluegrass (*P. bulbosa* L.) occurring widely as a winter turf in the Pacific northwest and the intermountain regions of Utah, and annual bluegrass (*P. annua* L.) used extensively throughout the USA on close-cut sports turf.

Present Germplasm Activities

One of the most common methods of producing new commercial cultivars of Kentucky bluegrass is to find and produce naturally occurring ecotypes. Some cultivars are the result of hybridization but due to apomixis a progressive recurrent selection program of breeding is not plausible. Collection and enhancement programs on Kentucky bluegrass are in progress in at least four public and ten or more private institutions in the USA. More than 30 public and private USA institutions are involved in evaluating Kentucky bluegrass cultivars and experimental strains through the National Turfgrass Evaluation Program. Preservation of commercial cultivars is done by the owners of cultivars and through the National Seed Storage Laboratory (NSSL). Regional Plant Introduction stations are also involved in the preservation of many *Poa* species. Currently, Kentucky bluegrass has 394 accessions seconded by bulbous bluegrass with 98 accessions. The remaining species have less than 25 accessions each, with the exception of Texas bluegrass which currently has none.

Status of Crop Vulnerability

Most of the present commercial turf type Kentucky bluegrasses have improved resistance to leaf spot and stripe smut. There is still need for sources of germplasm with resistance to the many races of powdery mildew, dollar spot, and stem, leaf, and stripe rust. The most devastating diseases of Kentucky bluegrass are patch-type diseases, the two most important of which are summer patch and necrotic ring spot. Screening for naturally occurring resistance to these diseases is beginning to show promise, but developing improved cultivars with resistance will likely require a long time. Important diseases in seed production fields of Kentucky bluegrass are ergot and stripe rust.

Bill bugs, sod web worms, chinch bugs, and grubs can seriously affect the quality of Kentucky bluegrass turf and none of the currently available cultivars have improved resistance.

Early in this century, bulbous bluegrass was used as a winter turf in the South. Evidence of this early use is still present today even though reseeding has not been performed for many decades. The value of this species, and others such as annual bluegrass needs to be assessed or reassessed in the light of present day societal needs.

Germplasm Needs

A. **Collection** - Because of the serious disease and insect problems on Kentucky bluegrass and the lack of resistance in present germplasm sources, there is a great need for additional collection work in this species; however, until there is a method of determining the uniqueness of new collections from existing introductions, additional collection efforts should focus on under represented species such as Texas bluegrass and annual bluegrass.

B. **Evaluation** - Present evaluation programs are adequate and should be continued.

C. **Enhancement** - There are breeding programs in progress to incorporate new sources of disease and insect resistance into Kentucky bluegrass. There need is to identify new and unique sources of germplasm that have insect and disease resistance and which may serve as candidates for hybridization work.

D. **Preservation** - Adequate.

Recommendations

Because Kentucky bluegrass is such an economically important and popular species for the turfgrass industry, there is a need to discover new sources of resistance to the important insect and disease problems. The next most economically important bluegrass for the turf industry would have to be annual bluegrass for which few collections have been made. There is a great need for additional germplasm collection activities for annual bluegrass which would be useful as assays for herbicide control and as breeding material for cultivar development.

RUSSIAN WILDRYE (*Psathyrostachys* Nevski)

K.B. Jensen

Species of the genus *Psathyrostachys* are commonly found on rocky open slopes and steppes from the Middle East and European USSR across central Asia to Northern PRC. Although ten species are included in the genus, only one, *P. juncea = Elymus junceus* (Russian wildrye), has gained importance as a forage grass (Dewey, 1984). The basic 'N' genome of *Psathyrostachys* also is found in combination with other genomes in *Leymus* (wildryes) and *Pascopyrum* (western wheatgrass) (Dewey, 1970b, 1972, 1984).

Once established, Russian wildrye is one of the best sources of grazing on semiarid rangelands of the Intermountain West and the Northern Great Plains. This cool-season perennial bunchgrass is native to the steppe and desert regions of the USSR and PRC. Although it was introduced in the USA in 1927, its value for reseeding depleted rangelands was not fully recognized until the 1950s (Hanson, 1972). Russian wildrye is resistant to drought and is characterized by dense basal leaves that are high in nutritive value and palatable to grazing animals. Although noted for its productivity during the early spring, its nutritive value is retained better during the late summer and fall than many other grasses, including crested and intermediate wheatgrass. Two relatively serious deficiencies have impeded the general acceptance of Russian wildrye on western rangelands: 1) The species is difficult to establish, particularly on harsh range sites and 2) Seed production is limited by the tendency of Russian wildrye to shatter soon after maturity.

The first cultivars from North American breeding programs, 'Vinall' and 'Sawki' were released in the 1950s and 1960s. Vinall was developed by the USDA-ARS at Mandan, NK, primarily on the basis of large seed, seed yield, and forage yield. Sawki, a ten-clone synthetic cultivar with improved forage and seed yield, was released by Agriculture Canada at Swift Current. In 1971, the cultivar Mayak was released from the breeding program at Swift Current. It was reported to be more productive than Sawki in terms of forage and seed (Hanson, 1972).

More recent developments from Russian wildrye breeding programs include the cultivars Swift, Cabree, and Bozoisky-Select. Swift was developed by Agriculture Canada at Swift Current primarily on the basis of improved seedling vigor. The new cultivar has demonstrated improved stand establishment vigor in Canadian evaluation trials (Lawrence, 1979). Cabree was developed by Agriculture Canada at Lethbridge with emphasis on improved seed retention or resistance to shattering (Smoliak, 1976).

'Bozoisky-Select' was released by the USDA-ARS breeding program at Logan, UT, (Asay et al., 1985b). The parental germplasm for this cultivar was derived from an introduction from the USSR (PI 406468, Bozoisky). During its development, the breeding population was subjected to recurrent screening for improved seedling vigor. Bozoisky-Select has been easier to establish and consistently more productive than Vinall on semiarid range sites.

Present Germplasm Activities

Of the ten species included in the genus *Psathyrostachys*, breeding and germplasm enhancement programs are limited to only Russian wildrye. Breeding and germplasm enhancement programs are being conducted by the USDA-ARS at Mandan, NK, and Logan, UT; with very limited programs at Swift Current, SK, by Agriculture Canada. Private industry does not support any breeding or germplasm enhancement research with this species. Improvement of seedling vigor has been a major objective in all of the active breeding programs (Asay and Johnson, 1980; Berdahl and Barker, 1984; Lawrence, 1979). Recently developed cultivars have demonstrated substantial improvements in vigor during stand establishment.

The first artificial tetraploid Russian wildrye cultivar Tetracan was released in 1988 by the Agriculture Canada Research Station, Swift Current, SK (Lawrence et al., 1990a). The parental germplasm originated from 27 clones treated with colchicine to induce chromosome doubling. Induced tetraploids of Russian wildrye reportedly have larger seeds and better seedling vigor than their diploid counterparts (Berdahl and Barker 1991, Asay et al., 1996). Additional tetraploid breeding populations artificial and natural have been developed through induced polyploidy and plant exploration by the USDA-ARS breeding programs at Logan, UT, and Mandan, NK. Native populations of tetraploid Russian wildrye have been introduced into the NPGS from Kazakhstan. Future emphasis within Russian wildrye breeding will be centered around the tetraploid germplasm populations.

Status of Crop Vulnerability

Currently, GRIN lists eight species within the genus *Psathyrostachys*, of which six, *P. huashanica* (1), *P. caduca* (0), *P. kronenburgii* (0), *P. lanuginosa* (0), *P. rupestris* (0), and *P. stoloniformis* (0), have one or no accessions. *Psathyrostachys fragilis* is represented by 11 accessions from Iran, northern Iraq, Armenia, and eastern Turkey. GRIN lists 165 accessions of Russian wildrye in the NPGS. Of these, 129 are from regions within the former Soviet Union with 25 additional accessions from China. A fewer number of accessions are held in the Canadian Gene Resources System. Breeding populations and experimental strains are held in storage by the breeding programs in the USA and Canada.

Russian wildrye included in early reseeding programs was derived from relatively few accessions. Although the problem was alleviated to some degree with the release of named cultivars in the 1960s, the parentage of Russian wildrye on North American rangelands stems from an extremely narrow genetic base.

Germplasm Needs and Recommendations

A. **Collection** - Plant exploration efforts must be expanded for natural tetraploid germplasm in the Eurasian interior, particularly in uncollected regions of the former Soviet Union and China to expand the genetic resources available to North

American enhancement and breeding programs. The present gene base within the tetraploid Russian wildrye is very narrow. With the rapid deterioration of native grasslands throughout Eurasia, there is a real urgency to collect and preserve the genes found in the other seven to nine *Psathyrostachys* species worldwide.

B. **Evaluation -** Recently acquired accessions of *Psathyrostachys juncea* (1989-94) have been evaluated for the basic descriptor and agronomic traits. Much of this data has been submitted to GRIN or is in the process of being compiled for submission to GRIN.

C. **Enhancement -** Poor stand establishment characteristics have prevented Russian wildrye from achieving its full potential on western rangelands. Selection for improved seedling vigor has been effective and significant genetic progress should be possible, particularly if germplasm pools can be upgraded through plant exploration. Induced polyploidy has shown promise as a breeding tool to increase seed size and subsequent seedling vigor in this species. It is recommended that research with these procedures be continued to develop tetraploid breeding populations.

D. **Preservation -** Efforts should be continued to maintain genetic diversity in the national germplasm banks with emphasis on tetraploid germplasm with stronger seedling vigor. The private sector has not and likely will not support breeding programs with Russian wildrye. Therefore, we strongly recommend that funding for public breeding programs with this potentially valuable range species be continued or expanded.

PSEUDOROEGNERIA spp.

K.B. Jensen

Pseudoroegneria is a genus in the Triticeae tribe of grasses, comprising up to 19 perennial species that had previously been included in *Agropyron* or *Elytriga* (Löve 1984). This genus consists of diploid (2n=14) and tetraploid (2n=28) taxa, and with the exceptions of *P. pretensis* and *P. deweyi* which are comprised of the S and P gemones, all remaining taxa contain only the S genome or some variation of it. As with *Agropyron*, the polyploid races of *Pseudoroegneria* are autoploid or near autoploid (Stebbins and Pun 1953, Dewey 1970a). In addition to being the foundation of *Pseudoroegneria*, the S genome is a component of all species of *Elymus* and found in selected taxa within the genus *Thinopyrum*. Bluebunch wheatgrass [*P. spicata* (Pursh) Löve] is the only North American species, but is a dominant component of many western range plant communities and an important range forage.

Two cultivars have been released, Whitmar was released in the 1940s, a result of selection of a superior population originating from the Palouse in eastern Washington. The cultivar Goldar was an increase of a population from Asotin County, WA, collected in 1934 for greater forage production and overall plant vigor (Gibbs et al., 1991). The cultivar Secar, sold on the commercial market as bluebunch, actually is thickspike wheatgrass, *Elymus lanceolatus*.

Old world species in limited evaluations at Logan, UT, show better overall vigor and production compared to the North American bluebunch. The old world species likely have been associated with man and livestock for a longer period, and therefore may have improved seedling vigor and resistance to grazing that populations of bluebunch wheatgrass lack. Much could be done to further domesticate native bluebunch wheatgrass, and the most apparent approach is to introduce desirable alleles from old world species.

Bluebunch wheatgrass has been used as a parent in crosses with quackgrass (*Elytrigia repens*) by the USDA-ARS at Logan to develop the RS hybrid (Asay and Dewey, 1981). The goal of this hybridization program is to combine the drought resistance and caespitose growth habit of bluebunch wheatgrass with the persistence under grazing, productivity, and salinity tolerance of quackgrass. The USDA-ARS at Logan also has developed an amphiploid hybrid between bluebunch wheatgrass and thickspike wheatgrass. This hybrid is presently being evaluated for possible use on arid range sites.

Bluebunch wheatgrass occurs on rangelands in Washington, Oregon, Idaho, Montana, California, Nevada, Utah, Wyoming, Colorado, British Columbia, and Alberta. About 50,000 pounds of seed are sold each year for reseeding projects. Demand is relatively low due to the high cost of seed and more difficult establishment compared to crested wheatgrass, intermediate wheatgrass, and other introduced species.

In the cool-season Intermountain West, bluebunch wheatgrass, crested wheatgrass (*Agropyron* spp.), pubescent/intermediate wheatgrass (*Thinopyrum* spp.), western wheatgrass (*Pascopyrum smithii*), and Russian wildrye (*Psathrostachys junceus*) form the basis for most of the range seeding mixtures. Each is recommended depending on the season of grazing use or other management criteria. They are the "backbone" species, and all have need of genetic improvement. Bluebunch and western wheatgrasses, although potentially valuable, are virtually unimproved.

Present Germplasm Activities

All current *Pseudoroegneria* germplasm activity is located at USDA-ARS Logan. Germplasm activities at Logan are limited to the selection of several superior populations (diploids and tetraploid) of bluebunch wheatgrass and the use of bluebunch as a gene source in several crosses with Snake River Wheatgrass. There are approximately 300 accessions of *P. spicata* and less than 85 accessions of old world species (*P. strigosa*, *P. libanotica*, *P. stipifolia*, *P. pretensis*, *P. geniculata*, and *P. cognata*) are held at Logan.

Based on the high level of chromosome pairing in the interspecific hybrids between the Eurasian and North American bluebunch wheatgrass complex, genetic exchange is possible. Due to the close genetic and morphological similarity among individuals of *P. spicata*, *P. strigosa*, *P. geniculata*, *R. elytrigioides* and *R. glaberrima* we are likely dealing with a single, polymorphic, Eurasian-North American species complex where *P. spicata* has nomenclatural priority (Jensen et al., 1995).

Status of Crop Vulnerability.

Most of the grassland soils that support bluebunch wheatgrass have been cropped. Much of the remaining grassland is overgrazed and infested with weeds such as cheatgrass (*Bromus tectorum* L.). Nevertheless, there are suitable areas for a representative collection of this species. However, with the rapid deterioration of the native grasslands within Eurasia, the old world Pseudoroegneria species are not adequately collected and future collecting trips should place emphasis on these species

Germplasm Needs and Recommendations

Through hybridization with other *Pseudoroegneria* and perhaps *Thinopyrum* and *Agropyron*, native bluebunch wheatgrass should be further domesticated to at least the level of crested wheatgrass.

A. **Collection** - A comprehensive assembly of old world *Pseudoroegneria* is necessary before superior lines can be developed through hybridization with bluebunch wheatgrass. Holdings of North American bluebunch wheatgrass are adequate. Assemble representative accessions of old world *Pseudoroegneria*. Emphasis should be on *P. strigosa* (including subsp. *aegilopoides*), *P. stipifolia*, *P. cognata*, *P. tauri*, *P. libanotica*, and *P. geniculata*. Collections from central Asia have highest priority (both former Soviet Union and China). Hopefully collections can be part of perennial Triticeae collection trips to this area.

B. **Evaluation** - Once assembled, old world accessions should be evaluated at Logan.

C. **Enhancement** - Through hybridization, *spicata*-based breeding populations are being developed with these attributes: improved seedling establishment, persistence under grazing, improved forage quality, targeted season of use, and drought tolerance.

D. **Preservation** - Existing accessions of bluebunch wheatgrass and new collections of old world *Pseudoroegneria* species should be maintained as part of the Triticeae group at Logan and currated at Pullman, WA. Efforts should be made to maintain genetic diversity in the national germplasm banks with an emphasis on ensuring that domestic collections held by the NRCS are not lost at the conclusion of their evaluations but included in the NPGS with selected material being sent to long-term storage.

STIPEAE SPECIES

T.A. Jones

Stipeae grass species number about 500 worldwide. About 10% of these are found in Anglo-America. Up to 200 others are found in Latin America. This group is cosmopolitan in scope (North and South America, Africa, Australasia, and Eurasia), appears to exhibit aneuploidy at the diploid level and has experienced a great deal of polyploidization in its evolution. Known chromosome numbers of Anglo-American species are 22, 26, 28, 32, 34, 36, 40, 42, 44, 46, 48, 64, 66, 68, 70, and 82. Much taxonomic uncertainty remains in the tribe because aneuploidy and its role in polyploid evolution are poorly understood and hybrids between species with widely different chromosome numbers may occur naturally. Because of the size of the group and its lack of extensive cytological study, differences of opinion concerning the status of genera and their boundaries will probably be unsettled for some time. While not universally accepted in North America, the treatments of the *Jepson Manual* (1993) and the forthcoming revision of Hitchcock's *Manual* recognize seven genera in Anglo-America. These include *Achnatherum* (28 spp.), *Hesperostipa* (4 spp.), *Nasella* (6 spp.), *Oryzopsis* (4 spp.) *Pipthatherum* (2 spp.), *Piptochaetium* (4 spp.), and *Ptilagrostis* (2 spp.). Traditionally, only *Stipa*, *Oryzopsis*, and *Piptochaetium* have been recognized in the USA.

While these grasses possess a C-3 photosynthetic pathway, they can only accumulate carbohydrates as starch in the chloroplast, not as fructans in the vacuole. Therefore, they show limited growth under cool temperatures and their ranges extend to warmer climates than fructan-accumulating cool-season grasses.

Only four cultivars are commercially available in the USA. Nezpar and Rimrock Indian ricegrass (*A. hymenoides*) are small-seeded cultivars adapted to the northern portion of the species range. Rimrock exhibits improved seed retention. Paloma is a large-seeded cultivar adapted to the southern portion of the range. Lodorm green needlegrass (*Nasella viridula*) was released for the Northern Great Plains on the basis of its reduced seed dormancy.

At least two species, drunkengrass (*A. inebrians*) from Asia and sleepygrass (*A. robustum*) from the southern and central Rocky Mountains, are of interest because of their narcotic effects on grazing ruminants. The narcosis is probably induced by lysergic acid derivatives produced by symbiotic endophytic fungi (*Neotyphodium* spp.). Their ability to deter grazing where reclamation exceeds animal production in importance make them potentially useful tools in range management.

Present Germplasm Activities

Several native species are receiving attention for rangeland seedings and restoration efforts. The USDA-NRCS (Lockeford, CA) is evaluating coastal and inland accessions of nodding needlegrass (*N. cernua*) and purple needlegrass (*N. pulchra*) collected from throughout the state. Needle-and-thread (*H. comata*) is being evaluated at NRCS locations at Los Lunas, NM, Bridger, MT, and Tucson, AZ. The Forest Service Shrub Sciences Laboratory (Provo, UT) has also initiated work with this species. Indian ricegrass evaluation is underway at Meeker, CO, Los Lunas, NM, and Logan, UT. Currently, evaluations are underway of Columbia needlegrass (*A. nelsonii* ssp. *dorei*) at Meeker, CO, New Mexico feathergrass (*H. neomexicana*) at Los Lunas, NM, Texas wintergrass (*N. leucotricha*) at Knox City, TX, and Thurber's needlegrass (*A. thurberianum*) at Aberdeen, ID, in cooperation with the Shrub Sciences laboratory.

Status of Crop Vulnerability

Germplasm in Anglo-America is probably not in danger of loss. Many of the species' ranges include the Intermountain West where much of the land is publicly owned and protected from overgrazing and development.

Germplasm Needs

A. **Collection -** Collection efforts should be directed toward the less commonly held species because a few account for a disproportionate number of accessions held by the NPGS. Since 90% of the species do not occur in Anglo-America, assembling a comprehensive collection of the tribe would be a large-scale effort with expeditions throughout much of the world. Since few species are considered economically important and many have seeds with long awns and a sharp callus, making them undesirable for livestock grazing, large-scale collections need to be justified on a biodiversity rather than a crop germplasm preservation basis.

B. **Evaluation -** The most economically important species in Anglo-America are Indian ricegrass and green needlegrass. Indian ricegrass accessions should be evaluated for seed dormancy, seedling vigor, seed yield, and seed retention. This species is highly ecotypic, and its broad diversity merits thorough evaluation. Green needlegrass and needle-and-thread, however, display relatively little genetic variation across a wide distribution. Accessions of drunkengrass and sleepygrass should be evaluated for presence of the endophyte, alkaloid production, and their nonpreference to grazing livestock.

C. **Enhancement** - Indian ricegrass has the greatest potential for improvement for rangeland vegetation. Indian ricegrass is self-pollinated and difficult to hybridize, but variation for critical traits can be found within its vast diversity and many of these traits are probably simply inherited.

D. **Preservation** - The NPGS holds 554 Stipeae accessions representing 66 taxa. However, three taxa (*A. hymenoides*, *Stipa capillata*, and *Piptatherum miliaceum*) account for 44% of the holdings and another six taxa account for 22%. Holdings at Logan, UT, include about 400 accessions of Indian ricegrass, 96 of sleepygrass, and 33 of green needlegrass. The NRCS Plant Materials Centers have significant collections for individual species that should be donated to the NPGS for long-term preservation to the extent that they can be processed with current resources.

Recommendations

Evaluation of current collections should be given a higher priority than collection of new accessions. Collection of new accessions should emphasize 1) Indian ricegrass because of its diversity and importance on western rangelands and 2) the many species with little or no representation in the NPGS.

INTERMEDIATE AND TALL WHEATGRASSES (*Thinopyrum* spp.)

K.P. Vogel

The nomenclature of the wheatgrasses has been recently revised (Barkworth and Dewey, 1985). Recommended names, former names, and the common names of the *Thinopyrum* species which were formerly in the genus *Agropyron* and that are economically important in the USA are listed below:

Intermediate wheatgrass:
Recommended name: *Thinopyrum intermedium* (Host) Barkw. and D.R. Dewey subsp. *Intermedium*
Former name: *Agropyrum intermedium* (Host) Beauv.

Pubescent wheatgrass:
Recommended name: *Thinopyrum intermedium* subsp. *barbulatum* (Schur) Barkw. & D. R.Dewey
Former name: *Agropyrum trichophorum* (Link) Richter

Tall wheatgrass:
Recommended name: *Thinopyrum ponticum* (Podp.) Barw. & D. R. Dewey
Former name: *Angropyrum elongatum* (Host) Beauv.

Intermediate and pubescent wheatgrasses are considered to be part of the same species complex since they readily intermate and differ only in the relative amount of pubescence on the spikes and leaves. In the rest of this section, they will be referred to collectively as intermediate wheatgrass. Intermediate and tall wheatgrasses are used primarily in the western half of the USA north of 35 N latitude in pastures, rangelands, and hay fields. Intermediate wheatgrass is less drought tolerant than the crested wheatgrasses, but it is more productive than crested wheatgrass in regions where precipitation is more than 15 inches per year. Tall wheatgrass is used primarily on saline soils throughout the western USA. It can produce good forage yields on soils that are too saline for other productive grasses to subsist. Intermediate wheatgrass produces high-quality forage, but the forage of tall wheatgrass is coarse and low in palatability when it approaches maturity. Both intermediate wheatgrass and tall wheatgrass are cross-pollinated. Statistics are not available on the number of hectares seeded to the intermediate and tall wheatgrasses in the USA.

Present Germplasm Activities

Breeding and germplasm enhancement research on the intermediate wheatgrasses is currently being conducted in the following public programs: USDA-ARS at Logan, UT, USDA-ARS at Mandan, ND, and USDA-ARS & Nebraska AES at Lincoln, NE. Tall wheatgrass breeding and enhancement research is being conducted in a small program by the USDA-ARS & Nebraska AES at Lincoln, NE. Agriculture Canada has breeding work in progress on intermediate wheatgrass at several locations. Private companies are not involved in any *Thinopyrum* breeding or enhancement research for forage or conservation. The current programs are emphasizing breeding for forage yield, forage quality, disease resistance, and seed yields. The ARS program at Logan has placed considerable emphasis on *Thinopyrum* collections and cytogenetic studies while the ARS program at Lincoln has emphasized the evaluation of introductions for forage yield and quality in replicated plots and the development of improved populations based on the better introductions. The ARS program at Mandan has emphasized disease resistance. The tall wheatgrass program at Lincoln is emphasizing improving forage quality.

Genetic Vulnerability

The most widely used intermediate wheatgrass cultivars are based upon a single plant introduction, PI 98568. Fortunately, intermediate wheatgrass is cross-pollinated, PI 98568 was a heterogenous collection, and breeders did not exert excessive selection pressure on PI 98568. Consequently, there is considerable genetic variability within most intermediate wheatgrass cultivars including those based upon PI 98568. There are over 250 intermediate wheatgrass PI lines in the NPGS. Intermediate wheatgrasses are native to eastern Europe and Asia, and collections have been made from parts of its range, but there are still many regions from which collections have not been made, particularly in the more arid regions of Asia. Overall, its genetic vulnerability is considered to be low-to-moderate. The same general situation exists for tall wheatgrass except less breeding work has been done with it. The most widely used tall wheatgrass cultivars are based on PI 98526. However, other cultivars are based on other introductions. Tall wheatgrass is native to Europe and Asia Minor. There are approximately 50 PI lines of tall wheatgrass in the NPGS. Additional introductions could be used to expand the germplasm base.

Germplasm Needs

A. **Collection -** The current intermediate and tall wheatgrass collections are considered to be adequate for existing breeding programs. Valuable germplasm has been identified in evaluation programs and is being used by current breeding programs. The collections of both grasses should be expanded. Collections should be made by plant explorers in unexplored regions of the USSR and PRC when other wheatgrasses are being collected.

B. **Evaluation -** All of the PI lines of intermediate and tall wheatgrass have been visually evaluated during increase at the Regional Plant Introduction Station. All intermediate, pubescent, and tall wheatgrasses in the germplasm system as of 1990 have been evaluated for forage yield and quality and other agronomic traits.

C. **Preservation -** Open-pollinated increase is to be avoided. A suggested method of increase that would maintain the genetic integrity of the accessions is to sib-pollinate the plants of an introduction by bagging spikes and transferring pollen between plants. This method will require additional funds for the labor involved in making the sib-pollinations. The seed should be stored in sealed, airtight containers at low temperatures to maintain seed viability over an extended period of time. This would decrease the need to periodically produce new seed lots.

Recommendations

A. Priority of actions--All introductions entered into the system since 1990 need to be evaluated for forage yield, forage quality and other agronomic traits. Research also needs to be conducted on effective, low-cost methods of increasing intermediate and tall wheatgrass accessions with minimal genetic contamination. All new accessions need to be evaluated by interested breeders using original seed lots and increased by sib-mating. Collections of these grasses need to be made in regions of the USSR and PRC that have not been previously explored for germplasm of these grasses. These collections should be made when plant collectors are going to these regions to collect other grasses and legumes.

B. Level of support--The cost of evaluating a set of 40 introductions for an array of agronomic traits including forage quality in a space-planted trial with four replicates is about $5,000 per year for a three-year evaluation period. One year would be used for establishment, and the two following years would be used for evaluating the lines. The cost of increasing PI lines by sib-pollination is not known, but it is estimated to be about $50 per PI line assuming 40 to 50 plants per PI line were bagged and sib-mated. If ten of the 200+ PI lines were renewed every year, the cost per year would be $500.

MISCELLANEOUS COOL-SEASON GRASSES

L.A. Brilman

***Koeleria* spp.**, junegrasses or hairgrasses, are native to both America and Eurasia. The type species, *Koeleria macrantha* (Ledeb.) J.A. Schultes (formerly *Koeleria cristata* auct. pro pate non Pers.), prairie junegrass or crested hairgrass, is found as a scattered component of native pastures or prairies throughout the western USA, is found in all areas except the southeast, is very plentiful in temperate areas of Europe and is very plentiful in western Mongolia. In addition to being a good forage grass, it shows excellent potential as a low-maintenance turfgrass for much of the USA and Europe, performing best with low nitrogen and able to withstand dry conditions.

Present Germplasm Activities

Currently, there is only one cultivar of prairie junegrass/crested hairgrass, the variety Barkoel, developed by Barenbrug from germplasm collected in southern England from a golf course. There are 96 accessions listed in GRIN, with 69 being *K. macrantha*. The majority of these are from a collection trip to Mongolia performed in 1994, and the material is not yet available. A recent trip in 1996 by Rutgers University through Bulgaria, Germany and Poland obtained more accessions, but these are not yet in the USA, having their initial increase in the Netherlands. Currently, there are two public and three private breeding programs that include junegrasses to some extent.

Status of Crop Vulnerability

Much of the native USA material was probably lost as prairies and native grasslands were plowed for farmland. In addition, nonnative species have become established in many areas. No extensive survey has been done on this genus in the USA or Europe with many of the collections as part of overall surveys of significant areas.

Due to the potential of this species as a forage, reclamation and turf grass it needs to be more thoroughly examined. Low seed production has been the biggest problem in most collected material and has hampered varietal development. Material from Poland shows much better potential (Meyer,W.A., personal communication) and since the genus has not been examined we do not know the true potential in all areas.

Germplasm Needs

A. **Collection** - The genus needs to be more thoroughly collected to better define the potential range and to obtain material for new cultivars.

B. **Evaluation** - Since no cultivars have been generally available it has been included in trials intended for other species, such as bluegrass and fine fescues. Rutgers University recently initiated a trial to better evaluate management as a turf. NTEP needs to develop a testing system with a prescribed management where alternative species can be evaluated.

C. **Enhancement** - Until we have a more extensive gene base this cannot be done.

D. **Preservation** - This genus shows great potential throughout the world and needs to be preserved *in situ* and by more extensive collections in additional areas.

Recommendations

This genus shows significant promise as a forage and turfgrass and should be more extensively collected and evaluated for both uses.

***Deschampsia* spp.**, hairgrasses, are cool season grasses found in mountain meadows, where it furnishes excellent forage, found in wetlands where it can be an important part of the vegetation, on mine spoils, on acid and sandy soils and in coastal marshes. They have also been collected in mown turf, especially in area of heavy wear. The type species is *D. cespitosa* (L.) Beauv. (also spelled *D. caespitosa*), tufted hairgrass, is a variable species found in many habitats in the northern hemisphere, throughout the Americas, Europe and into the arctic. *D. flexosa*, wrinkled, crinkled or wavy hairgrass is also circumpolar in distribution, is much finer textured and is used in England as a turf on acid soils and in shady sites.

Present Germplasm Activities

There are only three cultivars of tufted hairgrass in the USA. Peru Creek is a release from a heavy metal site below mines in Colorado, Nortran is from Palmer, Alaska from Iceland and native Alaska material for revegetation and turf and Norcoast from Native Alaska stands for revegetation and forage. Three experimental lines are in trials, one from Barenbrug, and two from Seed Research of Oregon, one from native Oregon selections, which appears more suited to wetlands usage, and one from British germplasm, which shows potential for both a wear tolerant turfgrass and a reclamation grass.

There are 79 accessions in the GRIN collection, 62 tufted hairgrass and 11 crinkled hairgrass. Three organization are examining the genus.

Status of Crop Vulnerability

The genus has been examined very little and much of the material was picked up in generalized surveys of specific sites. Further exploration of the range of types in the species needs to be done because those collected to date show great variability in seed yield potential, color, growth form, etc.

Germplasm Needs

A. **Collection** - More extensive collections, especially of the marginal sites where these species are found need to be done. As we look for species more adapted to salts, heavy metals and other problems including wear species such as this may be very valuable.

B. **Evaluation** - Turf evaluations have just started on these species and much further work needs to be done. They also need to be included in more reclamation and roadside trials. They have very ornamental seedheads, and there are some vegetative line available in the ornamental grass trade.

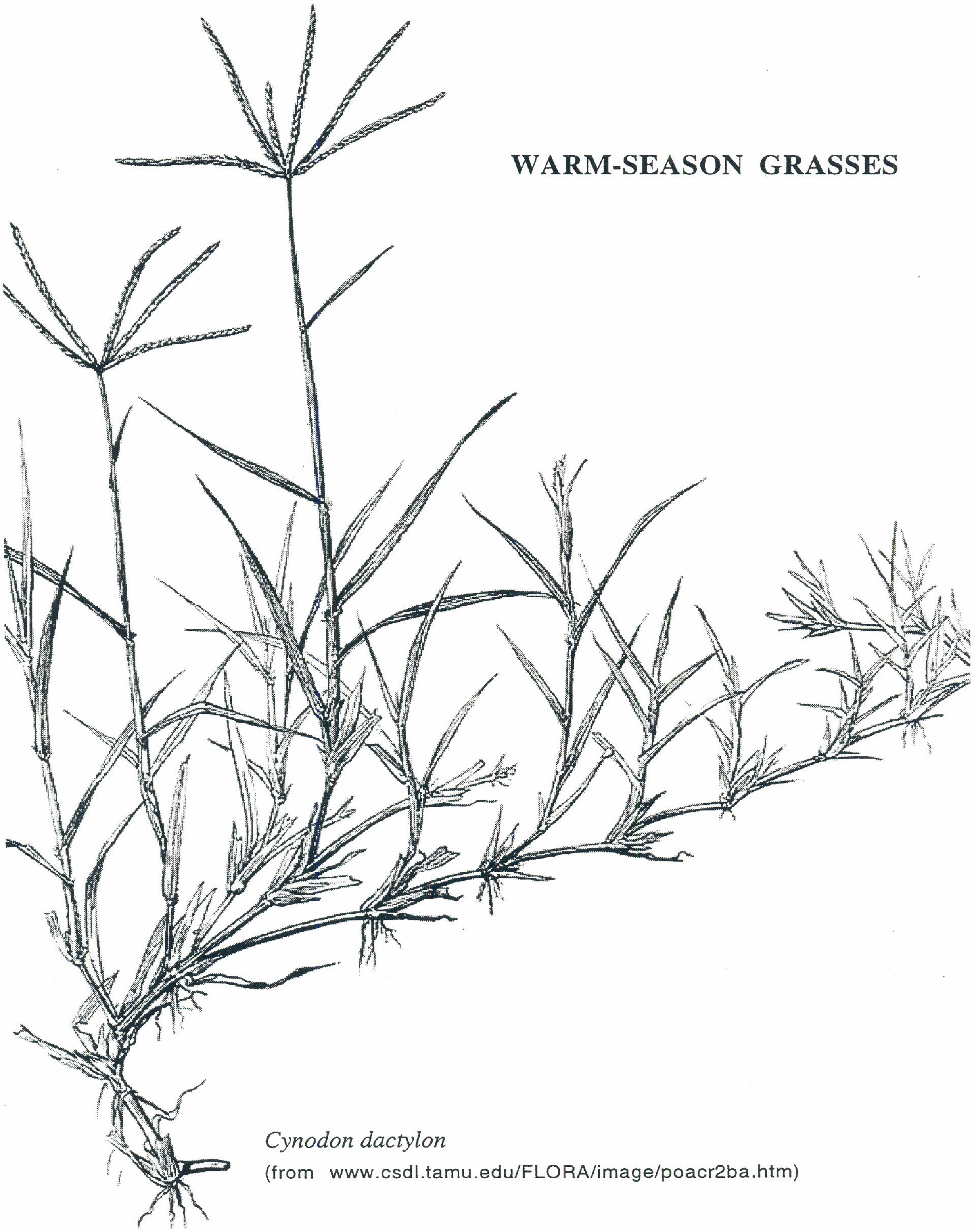
C. **Enhancement** - The first cultivars have primarily been selections of ecotypes. As more is known, further crosses and defined goals will be possible.

D. **Preservation** - We need to enhance the gene base of these species since they are found in our wetlands which have been decreasing worldwide and in many difficult environments.

Recommendations

These are species that deserve more examination based on further germplasm collections.

WARM-SEASON GRASSES



Cynodon dactylon
(from www.csdl.tamu.edu/FLORA/image/poacr2ba.htm)

BLUESTEMS *ANDROPOGON*

K.P. Vogel

Several species of *Andropogon* are native to the USA. The two with the most economic importance are big bluestem (*Andropogon gerardii* Vitman var. *gerardi*) and sand bluestem (*Andropogon gerardii* var. *paucipilus* (Nash) Fern. They are the only two species that have been used in breeding programs, and that are currently being used to seed pastures and rangeland. The two grasses are cross compatible, but since they are adapted to different soil types, common usage has been to treat them as separate species. Big bluestem is found in all the states east of the Rocky Mountains and in Utah and New Mexico. It was one of the principal grasses of the tall grass prairie. Sand bluestem was found throughout the Great Plains but was usually restricted to sandy soils. It is one of the dominant grasses in extensive areas such as the Nebraska Sandhills. Another important native bluestem is little bluestem, but it belongs to the genus *Schizachyrium.* Several introduced bluestems have considerable economic importance, but they are of the *Bothriochloa-Dichanthium-Capillidpedium* complex. Only the bluestems belonging to the genus Andropogon will be discussed in this section. Millions of acres have been seeded to mixtures containing these grasses in various programs such as the Conservation Reserve Program, but the number of acres remaining in grasslands is not known. These grasses have been used primarily in the Great Plains. Big bluestem is being used more extensively in the midwestern states as cultivars adapted to that region become available.

Present Germplasm Activities

Breeding and germplasm enhancement research on big and sand bluestem is currently being conducted in the USDA-ARS & Nebraska AES cooperative program at Lincoln, NE, the USDA-ARS grass breeding program at Woodward, OK, and at the South Dakota AES at Brookings, SD. Several of the Plant Materials Centers (PMCs) of the USDA-Natural Resource Conservation Service (NRCS) are also working with big and sand bluestem including Bismarck, ND, Manhattan, KS, Elsberry, MO, Booneville, AK, and Knox City, TX. The PMCs primarily collect, evaluate, and release selected ecotypes. The USDA-ARS and AES breeding programs are emphazing improving forage yield, forage quality, seed yield, and establishment capability. The cultivars being developed by these programs can be used in the Great Plains and midwestern States.

Genetic Vulnerability

Prior to settlement, major areas of the midwestern and Great Plains states of the USA were occupied by the tallgrass prairie. Most of this area has been plowed and is now the primary grain production area of the USA. Less than five percent of the original tallgrass prairie remains in the Midwestern states. In the Great Plains area, more extensive areas exist. In 1989, big bluestem was collected from remanent prairie sites in the North Central Region of the USA. The results of this collection indicate that there are numerous small prairie sites scattered throughout the former range of the tallgrass prairie, and that many are in public or conservatory ownership and are preserved. The array and extent of the preserved prairies is such that *in situ* preservation rather than seed storage should be the primary method of germplasm preservation of big bluestem. Information on the location of remnant prairies can be found in the National Heritage databases that are maintained by each state. The Nature Conservancy has assisted states in establishing the databases. The 1989 collections were evaluated in replicated trials at Mead, NE, Ames, IA, and West Lafayette, IN. The results indicate that there are significant differences among germplasm sources for an array of traits.

Both big bluestem and sand bluestem species are cross-pollinated via wind-blown pollen. Increasing seed of a large number of big bluestem germplasm accessions and maintaining genetic purity of individual accessions requires either a large number of field isolations or a considerable amount of hand labor to bag inflorescences and manually transfer pollen. Field and capitol resources are not available to increase and maintain individual accessions. Maintenance of individual accessions may not even be necessary. The big bluestem germplasm collected from remnant midwestern prairies in 1989 was classified by the USDA Plant Hardiness Zone of the collection site. Currently, big bluestem plants grown from seed collected from sites in Hardiness Zone 5 are being intermated in a large crossing block. Same procedure is being used for other Hardiness Zones. Seed produced in the crossing blocks will be used to establish a second generation intermating population. Seed produced from the second generation population (Syn 2) will be released as a germplasm composite. The germplasm composite for each Hardiness Zone will be placed in the USDA Germplasm system and will be made available to other breeders.

Several other big bluestem collections have been made at various times in different parts of the USA. These collections were evaluated, and the better accessions were used to develop existing cultivars and experimental strains. The remaining accessions for most of these collections have been lost or discarded because of the difficulty of maintaining genetic purity of this cross-pollinated grass. Currently, large collections of big bluestem are being maintained by the NRCS Plant Materials Center at Boonesville, AK. Previous collections were made by the South Dakota AES, Brookings, SD, and by the NRCS Plant Materials Centers at Bismarck, ND, and Elsberry, MO. Released cultivars of big bluestem are primarily improved populations with considerable genetic diversity. The released cultivars are primarily adapted for the Great Plains. Cultivars are available for use in many areas of the USA, such as the Midwest, are limited in number and availability. Cultivars of big bluestem are needed for warm-season pastures in many areas of the Midwest. Many of the sandy soils where sand bluestem is adapted are not suitable for cultivation, hence, sand bluestem is still found in extensive native stands throughout the Great Plains. The fate of the sand bluestem collections that have been made in the past is the same as the big bluestem collections. The best accessions were used to develop the existing cultivars and the remainder were lost. A few released cultivars are available for use in the central and southern Great Plains.

Germplasm Needs

A. **Collection** - Until breeding programs are in place that can utilize big bluestem germplasm, additional collections are not needed. The network of remanent prairies provides a source of germplasm that can be used by plant breeders when needed. *In situ* preservation can be fully utilized for this species. In recent years, some very sandy soils in the Great Plains have been plowed and have been farmed by using center pivot irrigations systems. This practice is no longer economical and this land needs to be revegetated with sand bluestem and other adapted grasses. Adapted cultivars are available. Big and sand bluestem collections may need to be made in the Southern Plains area to support the expanded breeding program at Woodward, OK.

B. **Evaluation** - In the past, all collections were evaluated for agronomic traits that could be visually scored. Many of these evaluations were done in unreplicated nurseries. Data on important traits such as forage quality were not collected. Most of the previous collections were discarded after the "best" material was selected from them. There is limited germplasm in the Plant Germplasm System that can be evaluated. The material that needs to be evaluated still needs to be collected. Any future collections should be evaluated in replicated nurseries for forage yield, quality, and other agronomic traits. There is a ploidy level series in big bluestem and ploidy levels of accessions should be determined.

C. **Enhancement** - All of the existing cultivars of big and sand bluestem were selected for adaptation to target environments, forage yield, seed yield, disease resistance, and establishment capability. These grasses are primarily utilized by grazing livestock, but none of the existing cultivars were selected or evaluated for forage-quality traits. Enhancement and breeding work on improving the forage quality of both big and sand bluestem. Enhancement work is needed to develop big bluestems that can be used in the Midwest and northeastern states for warm-season pastures.

D. **Preservation** - A limited number of collections are being held by the Plant Introduction System, but they are of limited value because most of them are the products of open-pollinated increase nurseries and, hence, are genetically contaminated. They need to be combined into composites during the next generation of seed increase. Most of the accessions that have been collected in the past have been lost because of the high cost and difficulty of maintaining the genetic purity of individual accessions of these cross-pollinated grasses. Emphasis should be placed on developing populations that are representative of the germplasm of an area rather than on individual plant collections. Separate populations should be developed for each ploidy level that is present in a region if resources are available for ploidy level determination. This approach would greatly increase the efficiency of preserving the genetic diversity of these cross-pollinated grasses by decreasing the number of PI lines that would have to be maintained.

Recommendations

Priority of actions--The USDA Plant Germplasm System needs to strongly support the National Heritage Program and the associated organizations and governmental units that are maintaining remnant prairie sites. These sites are the best available source of big bluestem germplasm and maintaining *in situ* sites is the most economical method of maintaining genetic diversity because most sites contain dozens of species in addition to big bluestem. When collections are made, the collected germplasm needs to be thoroughly evaluated in replicated trials for agronomic traits. The best collections can be used to form elite populations for use by plant breeders. All accessions from specific geographic regions such as the major land resource areas (MLRAs) used in land classification by the NRCS or USDA Hardiness zones should be used to form random-mating populations that will be representative of the genetic diversity of each region. Enhanced populations then could be used by any interested breeder as base populations for a breeding program and could also be maintained as seed in germplasm banks.

BUFFALOGRASS (*Buchloe*)

T.P. Riordan and P.G. Johnson

Buffalograss, *Buchloe dactyloides*, is found throughout the Great Plains from Canada, south to Mexico and is reported to be the most widespread of five closely related, monotypic, dioecious North American grasses. It is of major importance in the shortgrass rangelands of the USA. Development of 'Texoka' buffalograss, that produces a high percentage of seed bearing plants in its offspring, allowed the initiation of successful commercial seed production of this species. Harvests from rangelands produce much lower yields because of a low percentage of seed bearing plants, low soil fertility, and frequently inadequate moisture. Although only about one-half of buffalograss seed production is for turf, the primary target of present buffalograss germplasm research is turf.

Present Germplasm Activities

Germplasm activities with buffalograss are extensive. Major breeding efforts are underway at the University of Nebraska and the University of California-Davis. Additional germplasm research is underway at Texas Tech University, Seeds West, Phoenix, AZ, and Johnston Seed, Enid, OK. Improvement objectives include improved turfgrass quality, insect resistance, competitiveness with more aggressive species, sod density, greener color, improved sod strength, and characteristics for golf course use such as low-mowing tolerance.

Genetic Vulnerability

In general, buffalograss germplasm is not vulnerable. However, most commercial seed production is based on a single cultivar or several selections that have been used from Nebraska to Texas. A broader germplasm base is desirable.

Germplasm Needs

A. **Collection** - Relatively large collections have been made. About 1000 accessions have been available at Lincoln, NE, and Davis, CA. Although these collections are adequate in the short term, collections need to be made in peripheral areas of adaptation, at high altitudes and in 10-15 in./year rainfall zones.

B. **Evaluation** - Buffalograss germplasm is being evaluated at Lincoln, NE, and Davis CA, for turfgrass characteristics including: quality, density, color, insect resistance, low-mowing tolerance, sod strength, stand persistence and seed production. Germplasm diversity is being studied using RAPD molecular markers. Ploidy levels of clones and populations are also being determined.

C. **Enhancement** - Hybridization among buffalograss accessions is being done at Lincoln, NE, to obtain germplasm with desired combinations of characters mentioned above.

D. **Preservation** - At present, all preservation activities are carried on by the breeding programs in Nebraska and California. But these efforts are inadequate. As of 1996, only ten buffalograsses were listed as plant introductions. Clonal materials are important to breeding programs so preservation of these materials need to be addressed. Most wild germplasm is not endangered.

Recommendations

The present efforts of germplasm collection, evaluation, and enhancement are, in general, adequate. USA rangelands will continue to be the primary mechanism for most buffalograss germplasm preservation. However, preservation of more valuable parts of the collection, especially clonal materials, needs to be addressed.

1. Collect in peripheral areas of adaptation including areas of lower precipitation and higher elevations.

2. Continue evaluation/enhancement research at Lincoln, NE, and Davis, CA.

3. Determine ploidy levels and genetic diversity of germplasm.

4. Research into the gender determination mechanisms (genetic and physiological) should be a high priority.

5. Establish guidelines for preservation.

BUFFELGRASS (*Cenchrus*)

M.A. Hussey

Buffelgrass, *Cenchrus ciliaris* L. syn *Pennisetum ciliare* (L.) Link, is an important forage species throughout warm arid regions of the world (southwestern USA, Mexico, Africa, India, Australia). Acreage of buffelgrass in the USA and northern Mexico is estimated to be approximately six million acres, and its use in this region has more than doubled the livestock carrying capacity of south Texas pastures. The primary limitation of buffelgrass in the USA is its lack of winterhardiness which restricts its use to south of 30°N latitude. Buffelgrass is also grown in the drier regions of the Caribbean and South America, but its use is limited in those regions due to its susceptibility to the spittlebug and ergot.

Present Germplasm Activities

All germplasm activities in *Cenchrus* are located at College Station, TX, and involve a collaborative program between the USDA-ARS and TAES. Current activities include the evaluation and maintenance of working collection of buffelgrass, germplasm enhancement, and studies to better understand the genetic control of apomictic reproduction.

Overall germplasm activities may be summarized as follows:

1. Study the genetic control of apomixis.

2. Increase winter survival of buffelgrass through hybridization of nonwinter-hardy strains with winter-hardy pentaploid accessions collected in the Cape Province of South Africa.

3. Development of new sources of sexual germplasm.

4. Screen world collection of *Cenchrus* sp. for adaptation, mode of reproduction, etc.

5. Use of molecular tools to identify important gene(s) in forage crops.

Genetic Vulnerability

Since more than 90% of the buffelgrass acreage in south Texas and northern Mexico has been planted to a single apomictic land race (T-4464 or Common buffelgrass), the genetic vulnerability for the species is very high. In addition, the acreage planted to hybrid cultivars of buffelgrass trace their origins to a single female parent. In 1996, a leaf blight believed to be caused by *Pyricularia* spp. was observed on more than 70% of the buffelgrass acreage in south Texas. Other risks of concern include susceptibility of germplasm to ergot and spittlebug for which no genetic resistance has been identified.

Risk of genetic vulnerability may be reduced through the development and use of sexual plants derived from different geographic sources.

Germplasm Needs

A. **Collection** - The only germplasm collection effort was conducted by Dr. E.C. Bashaw in 1976. This collection trip to south Africa was extremely successful since it allowed us to identify new sources of facultative apomixis and cold tolerance. Additional collections need to be made in south Africa as well as from East Africa through India and should focus on buffelgrass and related perennial *Pennisetum* species. Major characters which are of importance include: 1) winterhardiness, 2) mode of reproduction (sexuality), and 3) adaptation to a wider range of soils. It is hypothesized that genes for winterhardiness are maintained in populations occurring at the lower elevations, and these sites should not be excluded from collection.

B. **Evaluation** - It is perceived that the objectives presented under germplasm activities are adequate at this time.

C. **Enhancement** - While it appears that the current efforts in germplasm enhancement are adequate at this time based on present plant materials, increased efforts on stress tolerance will be necessary as new sources of sexuality are identified. It is suggested that apomictic *Cenchrus* sp. represent an ideal "target species" for fundamental investigations of reproductive biology (control, regulation, and manipulation). It is proposed that efforts might be expanded to take advantage of emerging techniques in biotechnology in studying the "genetic and physiological regulation of embryogenesis in plants."

D. **Preservation** - The working collection at College Station, TX, contains many of the same introductions as the Regional Plant Introduction Center at Experiment, GA.

Efforts should be expanded for forage grasses to study improved methods of germplasm storage. These efforts should include, but not be limited to: 1) tissue culture (meristem), and 2) cold storage (freezing temperatures) of seed.

Recommendations

It is recommended that a series of plant exploration trips be conducted from south Africa through east Africa to northern India and southern China. Major objectives of such a collection trip would be to collect buffelgrass and related perennial *Pennisetum* species to identify genetic variability for winterhardiness, forage production potential, as well as "new" sources of sexuality within the complex.

BERMUDAGRASS (*Cynodon*)

C.M. Taliaferro

The genus *Cynodon* has near cosmopolitan distribution and contains species of economic importance as livestock herbage, turf, and soil erosion control. Bermudagrass (*C. dactylon* and *C. dactylon x C. nlemfuensis* or *C. dactylon x C. transvaalensis* interspecific hybrids) is the predominant introduced, warm-season, perennial, grass used in the southern USA for pasture, turf and soil stabilization. *Cynodon* is comprised of species or species ecotypes adapted to a wide range of climatic and edaphic conditions. The reproductive mode in the genus is sexual and predominantly outcrossing. Individual plants are easily propagated vegetatively, typically highly heterozygous, and vary greatly in fertility.

Present Germplasm Activities

The number of bermudagrass breeding programs in the USA has increased substantially over the past decade, with the greatest increase being in private sector programs. The private sector programs generally are emphasizing the development of seed-propagated, turf-type cultivars. In addition to turf *Cynodon* breeding, substantial breeding effort continues for forage and soil conservation-type bermudagrasses. The germplasms used in current programs trace mainly to the NPGS collection or to indigenous collections not incorporated into the NPGS collection.

Genetic Variability

Cynodon is comprised of nine species and ten varieties differing markedly in geographic distribution and morphological and adaptive diversity. *C. dactylon* is the one taxon in the genus with near cosmopolitan distribution and the greatest genetic diversity. It occurs worldwide between approximate latitudes 45° north and 45°- south. Ecotypic forms are adapted to climatic conditions ranging from tropical-to-temperate and arid-to-humid. Other taxa are less diverse but contain genetic variation of proven or potential value in genetic improvement programs.

Status of Germplasm Collections

A. **Collection** - The NPGS *Cynodon* collection maintained at the Southern Regional Plant Introduction Station, Griffin, GA, presently lists 482 accessions, many of these being individual clonally-propagated plants. Working collections that include many of the NPGS accessions are maintained at the headquarters sites of breeding programs, notably Tifton, GA, and Stillwater, OK. Original seed packets of approximately 150 *Cynodon* P.I.s collected by Oklahoma State University investigators in the 1960s are maintained in cold storage at OSU. The range of diversity within *Cynodon* is not represented in the current NPGS collection and is likely not represented in the NPGS, plus working collections. Accessions of some taxa are absent from the collections or present in token number. Though *C. dactylon* is best represented in current collections, its enormous variability probably is not captured in current collections because of voids in samples from large geographic regions such as Australia, Asia and eastern Europe. Additional collection from these regions is needed to better sample the genetic diversity and provide a greater array of germplasm for working collections. Further collection of *C. transvaalensis* from south Africa is needed for the same reasons. Because of the need to maintain many *Cynodon* accessions as vegetative clones long-term maintenance is difficult. Addition of accessions to the present collection in significant number will likely overwhelm existing maintenance capability. Establishment of a clonal repository for *Cynodon* and other clonally propagated species is desirable.

B. **Evaluation** - Accessions have been evaluated on an "as needed" basis by individual investigators for specific characters of interest. The entire NPGS *Cynodon* collection needs evaluation for selected standard descriptors. Evaluation of subsets of accessions for certain characters such as dry matter digestibility and freeze tolerance would be useful. Molecular DNA studies of genetic relatedness should be considered in relation to needs for forming core collections.

C. **Enhancement** - Basic breeding to effect population improvement in *Cynodon* germplasm pools has been minimal. Such effort is needed to provide superior breeding populations for the improvement of both seed- and vegetatively-propagated cultivars. Inter- and intra-specific hybridization to produce superior F_1 clonally propagated plants likely will continue as an important means of breeding; but having genetically enhanced germplasm from which to select parents for production of hybrids should help ensure success.

D. **Preservation** - Risk of loss of genetic diversity in wild *Cynodon* populations probably is low due to the general aggressiveness of most taxa and absence of serious insect or disease pests. However, there is genetic vulnerability associated with wide geographic use of relatively few clonally propagated commercial turf and forage cultivars. Consequently, the maintenance of adequate genetic diversity in the NPGS and working collections is needed to counteract the effects of devastating pest attacks, should they occur.

Recommendations (in priority order)

1. Evaluate the current NPGS *Cynodon* collection for standard descriptors.

2. Evaluate the need and potential for forming core *Cynodon* collections.

3. Additional germplasm collection is needed, particularly from geographic regions as noted above.

4. Develop a clonal repository for *Cynodon* and other vegetatively-propagated, warm-season perennial species.

LOVEGRASS (*Eragrostis*)

P.W. Voigt and M.A. Hussey

The genus consists of more than 300 species mostly tropical-to-subtropical in origin. Their greatest importance is in semiarid to arid areas for forage and for soil conservation. The two species native to North America that are of greatest importance are sand lovegrass, *Eragrostis trichodes*, found on sandy soils from Illinois west to Colorado and south to Texas, and plains lovegrass, *Eragrostis intermedia*, found on similar soils from Louisiana north to Missouri and west to Arizona. Cultivars of sand lovegrass are available for the central and southern Great Plains. The most important introduced lovegrass is *Eragrostis curvula*. Two forms of this grass are important in North America. Weeping lovegrass has been widely used for conservation purposes from New Jersey to Arizona and to a lesser extent for forage, primarily in the southern Great Plains. Boer lovegrass, *E. curvula* var. *conferta*, is important primarily for range revegetation in the desert grasslands and associated shrublands of the southwestern USA and Mexico. Weeping lovegrass has been planted on an estimated 500,000 acres in the southern Great Plains and is of great importance also in Argentina and southern Africa where it is native. Boer lovegrass is of importance also in Australia, where a cultivar was recently released, and in Africa. Lehmann lovegrass, *Eragrostis lehmanniana*, a close relative of *E. curvula*, is well adapted to parts of the desert grasslands of the southwestern USA and Mexico where it is used for revegetation of rangelands and for soil conservation. Lehmann lovegrass produces large quantities of seed and has sufficient "seedling vigor" to invade established stands of mesquite and of other grasses. Within the relatively narrow zone of precipitation and temperature to which it is well adapted, lehmann lovegrass appears to be expanding its range. Wilman lovegrass, *Eragrostis superba*, a native of east Africa, is of lesser importance in the USA. It is not closely related to the other introduced lovegrasses but has excellent potential for increased use because of its establishment ability and above-average forage quality for a warm-season grass. Tef, *Eragrostis tef*, an annual, is not used in the USA at the present time. It is important as a grain crop in Ethiopia and as a hay crop in a few other countries.

Present Germplasm Activities

No active federal, state, or private programs are being conducted with *Eragrostis* spp.

Genetic vulnerability

In general, the *Eragrostis* germplasm is not considered highly vulnerable. Plains and sand lovegrass germplasm is readily available for collection in the USA should the need arise. Because cultivars of weeping, boer, and lehmann lovegrass are highly apomictic, the germplasm currently in commercial use is not diverse. Most boer and lehmann lovegrass plantings in North America are of a single genotype. Most of the weeping lovegrass acreage consists of three genotypes that are probably relatively closely related. The germplasm enhancement effort with boer and weeping lovegrass addresses this lack of genetic diversity and impacts the lack of diversity in lehmann lovegrass as well. Wilman lovegrass and tef are of such limited importance in the USA that they cannot be considered vulnerable. Their vulnerability in an international perspective is not clear.

Germplasm Needs

A. **Collection** -

B. **Evaluation** -

C. **Enhancement** -

D. **Preservation** - Eragrostis germplasm is preserved at the Pullman, Washington Plant Introduction Station. About 950 accessions are maintained. As of 1985, that figure included 528 *E. curvula*, 6 *E.* intermedia, 55 *E. lehmanniana*, 55 *E. superba*, 46 *E. tef*, and 3 *E. trichodes*. Assuming that the PI station has adequate funds and personnel to maintain this germplasm, the present situation is adequate for most Eragrostis germplasm. Because most boer, weeping, and lehmann lovegrass germplasm is apomictic and tef is self-pollinated, those species can be increased without regard for isolation requirements and are ideal for PI station maintenance. However, all sexual PIs should be identified and increased in isolation. Wilman lovegrass is cross-pollinated and should be handled differently. A limitation of the Pullman station is that it is located outside the area of adaptation of these and most other warm-season grasses. While many *Eragrostis* introductions are sufficiently winterhardy to survive at Pullman, others are not and would have to be handled as annuals at that location.

Since no federal or state programs are presently working on lovegrass, the sexual germplasm formerly maintained at Temple, TX, is vulnerable to loss.

Recommendations

Sexual germplasm in this collection is at high risk for loss and should be preserved.

CENTIPEDEGRASS
(*Eremochloa ophiuroides*)

W.W. Hanna

Centipedegrass *(Eremochloa ophiuroides)* is a popular, low-growing, low maintenance, acid soil and drought-tolerant turf species used in lawns and recreational areas from Texas to North Carolina. Until recently, most centipedegrass had been derived from a single introduction collected in China in 1918. Twenty-six accessions were collected in Taiwan in 1985. Five accessions have been obtained from China since 1981.

Present Germplasm Activities

Most centipedegrass germplasm research is conducted by the USDA-ARS at the Coastal Plain Experiment Station, Tifton, GA.

Genetic Vulnerability

The gene base of centipedegrass planted in the USA is narrow and genetic diversity is limited. The narrow gene base of all centipedegrass planted on lawns across the South does result in a risk if a disease or insect should become a problem in the future.

Germplasm Needs

A. **Collection** - There were less than 35 accessions in the USA, and these were maintained at Tifton, GA. These accessions have been put into a random-mating population. The use of centipedegrass will increase in the future mainly by being used in lawns farther north than presently used. Accessions are needed from central and southern China to broaden the gene base.

B. **Evaluation** - Current evaluation is adequate because only a few accessions are available.

C. **Enhancement** - Radiation is being used to create variability. Random mating populations of various accessions are being developed to broaden the gene base and produce new recombinant types. This will continue.

D. **Preservation** - A random-mating population with 31 foreign and 24 domestic accessions is maintained at the Coastal Plain Experiment Station, Tifton, GA. It does not represent the genetic diversity of the species.

Recommendations

Priority of action--The greatest need for this genus is to collect *E. ophiuroides* in southern and central China and *E. muricata*, a related stoloniferous species, from India (and surrounding areas) and Thailand. This would involve two separate collection trips to China and one trip to the India-Thailand areas.

Interest in turf and centipedegrass in China has greatly increased. Key botanists and researchers have been identified in China who are interested in making a systematic collection of this species in its center of origin.

KLEINGRASS (*Panicum*)

M.A. Hussey

The genus Panicum is a large genus consisting of annuals and perennials with approximately 500 species distributed throughout the world, mainly in the tropics. Kleingrass, *Panicum coloratum* L., is a tetraploid, cross-pollinated species that has been planted on more than 1.25 million acres in Texas, New Mexico, and Arizona. Its value to the livestock industry has been restricted because its range of adaptation is limited by a lack of winterhardiness. Kleingrass is viewed as having superior forage nutritive value compared to most warm-season grasses with animal gains being superior to those obtained on *Cynodon* pastures. Kleingrass is often an important component of mixtures with native grasses.

Present Germplasm Activities

No germplasm activities are being conducted by the USDA-ARS or SAES at this time.

Genetic Vulnerability

The genetic variability of this species is unknown, however, the small number of accessions which have been utilized in the development of the two commercial cultivars suggests the possibility of future problems.

Germplasm Needs

A. **Collection -** Although no active programs are currently working on Kleingrass, this is an economically important forage species. Collection of additional germplasm should be included as an objective on other plant collection trips to East Africa.

B. **Evaluation -**

C. **Enhancement -**

D. **Preservation -** Germplasm maintenance encounters the same problems as are generally found in cross-pollinated species with a high degree of self-incompatibility. Preservation of existing germplasm is critical with the lack activity by state and federal programs

Recommendations

Because of the economic importance of this species, efforts should be made to maintain and acquire new germplasm of Kleingrass even though there are no active forage improvement programs working with this species.

SWITCHGRASS (*Panicum virgatum*)

K.P. Vogel

There are numerous species of *Panicum* that are native to the USA, but the species that has the greatest use and potential as a domesticated grass is *Panicum virgatum* L. Switchgrass is found naturally in all the continental states except California, Oregon, Washington, and Idaho, and it was one of the principal grasses of the tallgrass prairie. In the Great Plain states, it is one of the principal grasses for pasture, range, and conservation plantings and in the Midwest and northeastern states it's used as a pasture and conservation grass is steadily increasing. It has been identified by the USA Department of Energy (DOE) as the most promising perennial, herbaceous species available for development into a biomass fuel crop. DOE is funding research in several regions of the USA on switchgrass breeding and management. Breeding programs for development of switchgrass into a biomass fuel crop are the USDA-ARS and University of Nebraska cooperative program at Lincoln, NE, and Oklahoma State University at Stillwater, OK. DOE supported programs on breeding switchgrass are being initiated at the University of Georgia and the University of Wisconsin. Switchgrass has the C4 photosynthetic system and is very productive during the hot summer months in these regions. Statistics are not available on the number of acres seeded to switchgrass. If suitable cultivars are developed, it will become one of the main pasture grasses in the regions where it is adapted. If adequate energy conversion technology is developed, it could be grown on millions of acres of marginal crop land in the eastern half of the USA.

Present Germplasm Activities

Breeding and germplasm enhancement research on switchgrass for use as a forage and conservation grass is currently being conducted by the ARS-USDA & Nebraska AES cooperative program at Lincoln, NE, and the South Dakota AES at Brookings, SD. Plant Material Centers (PMC) of the National Resource Conservation Service-USDA located in Texas, Missouri, Kansas, Michigan, North Dakota, Arkansas, Florida, New York, and Georgia are also working with switchgrass. The PMCs primarily collect, evaluate and then release the best accessions or ecotypes as cultivars. The ARS and AES programs are emphasizing improving forage yield, forage quality, seed yield, and establishment capability.

Genetic Vulnerability

Prior to settlement, major areas of the midwestern and Great Plains states of the USA were occupied by the tallgrass prairie. Most of this area has been plowed and is now the primary grain production area of the USA. Less than five percent of the original tallgrass prairie remains in the midwestern states. In the Great Plains area, more extensive areas exist. In 1989, switchgrasses were collected from remanent prairie sites in the North Central Region of the USA. The results of this collection indicate that there are numerous small prairie sites scattered throughout the former range of the tallgrass prairie, and that many are in public or conservatory ownership and are preserved. The array and extent of the preserved prairies is such that *in situ* preservation rather than seed storage should be the primary method of germplasm preservation of switchgrass. Information on the location of remnant prairies can be found in the National Heritage databases that are maintained by each state. The Nature Conservancy has assisted states in establishing the databases. The 1989 collections were evaluated in replicated trials at Mead, NE, Ames, IA, and West Lafayette, IN. The results indicate that there are significant differences among germplasm sources for an array of traits.

There are two main ecotypes of switchgrass, lowland and upland. Lowland types are all tetraploids while upland ecotypes are tetraploids or octaploids. Both upland and lowland switchgrasses are cross-pollinated via wind-blown pollen. Increasing seed of a large number of switchgrass germplasm accessions and maintaining genetic purity of individual accessions requires either a large number of field isolations or a considerable amount of hand labor to bag inflorescences and manually transfer pollen. Field and funding resources are not available to increase and maintain individual accessions. Maintenance of individual accessions may not even be necessary. The switchgrass germplasm collected from remnant midwestern prairies in 1989 was classified by the USDA Plant Hardiness Zone of the collection site. Currently, switchgrass plants grown from seed collected from sites in Hardiness Zone 5 are being intermated in a large crossing block. The same procedure is being used for other Hardiness Zones. Seed produced in the crossing blocks will be used to establish a second generation intermating population. Seed produced from the second generation population (Syn 2) will be released as a germplasm composite. The germplasm composite for each Hardiness Zone will be placed in the USDA Germplasm system and will be made available to other breeders.

Several other switchgrass collections have been made at various times in different parts of the USA. These collections were evaluated, and the better accessions were used to develop existing cultivars and experimental strains. Currently, large collections of switchgrass at Mead, NE, and Stillwater, OK. Released cultivars of switchgrass are primarily improved populations with considerable genetic diversity. The released cultivars are primarily adapted for the Great Plains states. Cultivars are available for use in many areas of the USA, such as the Midwest, are limited in number and availability, although new cultivars are being developed and released for these regions. Cultivars of switchgrass are needed for warm-season pastures in many areas of the Midwest. Cultivars for specific use in biomass fuel production will differ in phenotype from those developed for use in pastures. Cultivars developed for specific use as biomass fuel crops remain to be developed. Improved cultivars of switchgrass are needed in the northeastern and southeastern USA. Germplasm collection and germplasm evaluation work is needed in these regions for switchgrass.

<u>Germplasm Needs</u>

A. **Collection** - Switchgrass cultivars need to be developed for use in pasture, conservation, and probably also biomass plantings in the Northeast and southeast USA. Before this can occur, germplasm must be collected, evaluated, and enhanced. Research at both Nebraska and North Carolina demonstrates that there is substantial genetic variability for most agronomic traits in switchgrass. Germplasm needs to be collected from relic stands in all regions in which switchgrass was a component of the native vegetation, evaluated, and enhanced.

B. **Evaluation** - In the past, all collections were evaluated for agronomic traits that could be visually scored. Many of these evaluations, were done in unreplicated nurseries. Data on important traits such as forage quality were not collected. Most of the previous collections were discarded after the "best" material was selected from them. There is limited germplasm in the Plant Germplasm System that can be evaluated. This material requiring evaluation still needs to be collected. Any future collections should be evaluated in replicated nurseries for forage-yield, quality, and other agronomic traits. Because of the potential of switchgrass as a biomass fuel plant, accessions should also be evaluated for biomass production. Superficial visual evaluations need to be de-emphasized. There is a ploidy level series in switchgrass and ploidy levels of accessions should be determined.

C. **Enhancement** - All of the existing cultivars of switchgrass were selected for adaptation to target environments, forage yield, seed yield, disease resistance, and establishment capability. Switchgrass is primarily used by grazing livestock but none of the existing cultivars, except for 'Trailblazer,' were selected or evaluated for forage quality traits. None of the available cultivars were selected for use as biomass fuel plants. Enhancement and breeding work is needed to improving the forage quality of switchgrass and for use as a biomass crop. There are specific needs to develop switchgrass cultivars that are adapted to the northeastern and southeastern USA for use as a forage crop. Enhancement and breeding work is needed to develop switchgrass into a biomass fuel crop for all areas of the USA east of 100 W. longitude This enhancement work must be preceded by germplasm collection and evaluation.

D. **Preservation** - A limited number of collections are being held by the Plant Introduction System but they are of limited value because most of them are the products of open-pollinated increase nurseries and, hence, are genetically contaminated. They need to be combined into composites during the next generation of seed increase. Most of the accessions that have been collected in the past have been lost because of the high cost and difficulty of maintaining the genetic purity of individual accessions of these cross-pollinated grasses. Emphasis should be placed on developing populations that are representative of the germplasm of an area rather than on individual plant collections. Separate populations should be developed for each ploidy level that is present in a region if resources are available for ploidy level determination. This approach would greatly increase the efficiency of preserving the genetic diversity of these cross-pollinated grasses by decreasing the number of PI lines that would have to be maintained.

Recommendations

Priority of actions--The USDA Plant Germplasm System needs to strongly support the National Heritage Program and the associated organizations and governmental units that are maintaining remnant prairie sites. These sites are the best available source of switchgrass germplasm and maintaining *in situ* sites is the most economical method of maintaining genetic diversity because most sites contain dozens of species in addition to switchgrass. When collections are made, the collected germplasm needs to be thoroughly evaluated in replicated trials for agronomic traits. The best collections can be used to form elite populations for use by plant breeders. All accessions from specific geographic regions, such as the major land resource areas (MLRAs) used in land classification by the NRCS or USDA Hardiness Zones, should be used to form random-mating populations that will be representative of the genetic diversity of each region. Enhanced populations then could be used by any interested breeder as base populations for a breeding program and could also be maintained as seed in germplasm banks. Germplasm collection and evaluation of switchgrass need to be made for the eastern half of the USA to support the switchgrass biomass breeding programs.

PASPALUM

B.L. Burson

The genus *Paspalum* consists of more than 300 species which are native to the Americas. The two most important forage grasses are dallisgrass (*P. dilatatum*) and bahiagrass (*P. notatum*). Both species are native to South America, but they have become naturalized in the southern USA where they are grown on several million hectares. In addition to these two grasses, there are a number of other *Paspalum* species with forage and conservation potential. These include brown seeded paspalum (*P. plicatulum*), brunswickgrass (*P. nicorae*), longtom (*P. lividum*) and others. The USDA-NRCS has expressed an interest in these species for several years. Seashore paspalum (*P. vaginatum*) is another species which has recently received considerable attention as a turf grass.

Present Germplasm Activities

Germplasm research activities on the genus are by the USDA-ARS and Texas A&M University at College Station, TX, USDA-ARS at Tifton, GA, and University of Georgia at Griffin. The program at College Station is concentrating on dallisgrass and several other *Paspalum* species, while the program at Tifton deals primarily with bahiagrass. The program at Griffin addresses seashore paspalum.

The undesirable characteristics in dallisgrass are susceptibility to ergot (*Claviceps paspali*), low-seed set, and low-forage yields. However, common dallisgrass is an obligate apomict, and all germplasm of this biotype is extremely uniform and variability for the above traits has not been found. Intra- and interspecific hybridizations are being used to circumvent apomixis and develop sexual germplasm to be used in a breeding program. At Tifton, the major efforts with bahiagrass are to increase forage yield, drought tolerance, and cold tolerance. The program at Griffin is focused on developing improved seashore paspalum types as turfgrasses by selecting for improved persistence, salt tolerance, and disease resistance.

Genetic Vulnerability

Because common dallisgrass is an obligate apomict, essentially all of the dallisgrass in the USA is genetically the same. This makes dallisgrass vulnerable to new insects and diseases. Its susceptibility to ergot demonstrates this vulnerability.

Bahiagrass is not as vulnerable as dallisgrass because both sexual and apomictic accessions are available. The sexual plants are cross-pollinated which increases their heterozygosity. However, the genetic base of the sexual bahiagrass is relatively narrow because most of the available sexual germplasm were collected from the same geographical area. The acquisition of additional sexual germplasm from different locations would be desirable.

Seashore paspalum is a stoloniferous species and much of it has been propagated vegetatively which suggests a narrow genetic base. However, the species produces viable seed and morphologically diverse types exist in nature. DNA analysis suggests that the germplasm assembled at Griffin, GA, can be separated into six different genetic clusters.

Germplasm Needs

A. **Collection** - More than 1000 *Paspalum* accessions are maintained in the National Plant Germplasm System; however, additional germplasm is needed. Much of the available germplasm has been evaluated. Because the genus is so large and diverse, many *Paspalum* species have never been collected and are not in the NPGS. As this germplasm is collected and evaluated, it is not uncommon for species which are new to the NPGS to have potential as forage grasses. For example, an accession *P. atratum* was introduced into the USA only a few years ago, and the University of Florida is in the process of releasing it as a cultivar. Additional germplasm of the *Plicatula* group is needed as well as the hexaploid dallisgrass biotypes, seashore paspalum and sexual bahiagrass.

B. **Evaluation** - Most of the germplasm collected in South America during the 1970s has been evaluated for chromosome number, cytological behavior, method of reproduction, seed set, adaptability, susceptibility to ergot, and forage potential. Some of the accessions in the NPGS that were collected prior to the 1970s also have been evaluated for the above traits.

C. **Enhancement** - Because of apomixis and the lack of variation in common dallisgrass, enhancement by conventional grass breeding methods is not feasible. Apomixis is prevalent in many of the other *Paspalum* species and this has been an impediment to improvement. However, sexual types have been discovered in some of the predominantly apomictic species which opens a means for genetic improvement. Unfortunately, many of the species that have sexual forms are highly self-pollinated which requires tedious hand emasculations and pollinations to produce hybrids. Cell and tissue culture techniques have been used to create somaclonal variation in common dallisgrass and efforts are continuing with hexaploid dallisgrass in Louisiana.

Bahiagrass enhancement has been ongoing for many years at Tifton, GA, using primarily the available sexual germplasm. For the past several years, the approach used has been Recurrent Restricted Phenotypic Selection.

The seashore paspalum improvement program at Griffin, GA, is selecting superior ecotypes for turf types and using tissue culture techniques to produce superior somaclones.

D. **Preservation** - Seed of essentially all of the *Paspalum* accessions in the USA are stored at the Southern Regional Plant Introduction Station in Griffin, GA. Some of the same accessions are also maintained at College Station, TX, and Tifton, GA. A large vegetative collection of seashore paspalum is maintained at Griffin, GA. Because many of the species are apomictic, loss of genetic purity from cross-fertilization is not a problem. With the exception of sexual bahiagrass, most sexual *Paspalum* species are highly self-pollinated and maintenance of genetic purity of open-pollinated seed is not a problem.

Recommendations

A. Priority of action--Additional germplasm needs to be collected primarily in South America.

B. Proper identification of germplasm in the NPGS continues to be a problem. This is especially true for many of the warm-season grasses, including the genera *Paspalum*, *Pennisetum*, *Panicum*, *Cynodon*, and others. A person with expertise in the identification and classification of warm-season grasses should be added to the staff of the NPGS.

FORAGE-TYPE *PENNISETUMS* (*Pennisetum* spp.)

B.L. Burson

The genus *Pennisetum* is composed of about 120 species which grow in the tropics and subtropics and to a lesser extent, in the warm temperate areas throughout the world. A number of species are excellent forage grasses, and others are used for conservation purposes. In addition to those species mentioned in the "Pearl Millet Section," there are other species in which additional germplasm is needed. Flaccidgrass (*P. flaccidum*) is a species with considerable forage potential in the southeastern USA. It is indigenous to the higher elevations of central Asia. Its area of adaptation in the USA extends from southeastern Pennsylvania south to the mountainous and piedmont regions of Georgia and west to eastern Oklahoma. Low seed production is the major factor limiting this species. Other *Pennisetum* species that could be of value in the southeastern USA are *P. orientale* and *P. mezianum*; however, lack of winterhardiness limits these species.

Present Germplasm Activities

A cooperative effort between Texas A&M University and USDA-ARS at College Station, TX is the only program addressing these species. Accessions of several different *Pennisetum* species have been characterized cytologically and evaluated for adaptation with emphases on winterhardiness, seed production, forage production and forage quality. Interspecific hybrids have been produced and investigated. Some of the hybrids appear to have potential as forage grasses with increased cold tolerance.

Genetic Vulnerability

The genetic base of all the grassy *Pennisetum* species is extremely narrow because the number of accessions in the NPGS is very limited.

Germplasm Needs

A. **Collection** - There are less than 15 flaccidgrass accessions in the USA. The same is true for *P. orientale* and *P. mezianum*. In fact, there are only two *P. mezianum* accessions in the NPGS. This demonstrates the shortage of available germplasm of these species. Additional germplasm is drastically needed for all of the *Pennisetum* forage species.

B. **Evaluation** - Essentially all of the available accessions have been evaluated.

C. **Enhancement** - The only enhancement work has been interspecific hybridization between *P. flaccidum*, *P. orientale*, *P. mezianum*, and several other *Pennisetum* species. The research was for basic cytological investigations, but some of the interspecific hybrids were vigorous and have potential as a forage grass.

D. **Preservation** - The limited amount of available germplasm is maintained at the Southern Regional Plant Introduction Station, Griffin, GA.

Recommendations

Several well planned plant collection trips need to be made to the eastern and sub-Sahara areas of Africa and the Himalayas from Afghanistan to southwestern China.

PEARL MILLET (*Pennisetum glaucum*) and WILD *PENNISETUMS*

W.W. Hanna and B.L. Burson

Pearl millet (*Pennisetum glaucum*) is an important temporary summer forage crop in the southern half of the USA. It is an important world food crop with over 50 million acres grown for this purpose. There is a new interest in pearl millet for grain production in the USA because of its excellent drought tolerance (better than any major grain crop), tolerant of wide pH range, efficient nitrogen utilization, high-quality grain, etc. Breeding dwarf pearl millet grain hybrids has just begun in the USA. Some experimental hybrids have yielded 5000-6000 pounds of grain per acre. Pearl millet could be grown for grain across the entire South. It is also being grown successfully in Kansas and Nebraska (short season hybrids). Pearl millet for grain in the USA is a "sleeping giant."

The genus *Pennisetum* is composed of about 120 species which grow in the tropics and subtropics and to a lesser extent, in the warm temperate areas throughout the world. A number of species are excellent forage grasses and others are used for conservation purposes. Three species that have considerable forage potential in the southeastern USA are flaccidgrass (*P. flaccidum*), *P. orientale* and *P. mezianum*. However, low seed production is the major limiting characteristic of flaccidgrass. Lack of winterhardiness limits the use of *P. orientale* and *P. mezianum*.

<u>Present Germplasm Activities</u>

The major germplasm activities are by the USDA-ARS at the Coastal Plain Experiment Station in Tifton, GA; Kansas State University, Hays, KS; University of Nebraska, Lincoln, NE; and Texas A&M University and USDA-ARS in College Station, TX. Personnel at Tifton, GA, handle the curator responsibilities. Kansas and Nebraska are producing and evaluating dwarf populations and hybrids for grain. Georgia is involved in developing high-quality, commercial forage hybrids, production and evaluation of dwarf grain hybrids, germplasm transfer from wild species to cultivated pearl millet, developing more efficient breeding methods, conversion of introductions to adapted USA genotypes, and evaluation of the wild species germplasm. Accessions and interspecific hybrids of several different *Pennisetum* species have been characterized cytologically and evaluated for adaptation with emphases on winterhardiness, seed production, forage production and forage quality in Texas.

<u>Genetic Vulnerability</u>

Cultivated pearl millet has been thoroughly collected in most African countries by mainly ICRISAT, IBPGR, and the French. There are some 20,000 accessions at ICRISAT in India. Approximately 2500 of these are maintained at the Southern Regional Plant Introduction Station and Tifton, GA.

The greatest risk involves losing the wild species and the grassy pearl millet subspecies, *monodii*, which is located in the Sahel of Africa from Senegal to Sudan. Limited research with this subspecies in Georgia has shown it to be a source of genes for resistance or immunity to many of the diseases and pests of pearl millet. It has excellent yield genes and appears to be a valuable source of needed cytoplasmic diversity. The genes in *monodii* can be readily used in pearl millet though an intense backcrossing and selection program.

The wild *Pennisetum* species (tertiary gene pool of pearl millet) have not been collected systematically. These wild species need to be collected because most are immune to all diseases of pearl millet. Many are apomictic and could be sources of genes for producing true-breeding hybrids in our agronomic crops in the future. Some are extremely drought tolerant. These wild species need to be collected in central Africa and central and South America.

<u>Germplasm Needs</u>

A. **Collection** - Germplasm representation appears to be adequate for pearl millet. Germplasm representation for subspecies, *monodii*, and the wild *Pennisetum* species is poor. There are about 250 accessions of *monodii* at Tifton, GA, (largest collection) and about 200 wild species accessions at Tifton, GA, (largest collection). Less than 20 of the 140 known *Pennisetum* species are represented in the collection. Additional germplasm is drastically needed for all of the *Pennisetum* forage species. For example, there are less than 15 flaccidgrass accessions in the NPGS, and the same is true for *P. orientale* and *P. mezianum*. In fact, there are only two *P. mezianum* accessions in the NPGS.

   Plant Introduction and Plant Quarantine have been very cooperative in introducing germplasm. It would be helpful if introduction of vegetative material could be simplified and clearance hastened. There is a great need for space at St. Croix to grow out short-day sensitive introductions.

B. **Evaluation** - Wild accessions are currently increased under quarantine and stored. Some information is being obtained on disease reaction, chromosome number, and reproductive behavior. A more thorough and systematic evaluation is needed for agronomic potential such as testing *monodii* accessions in hybrid combinations with pearl millet to identify yield genes.

C. **Enhancement** - The greatest rapid benefits will come from introgressing genes from *monodii* and *Pennisetum purpureum* to cultivated pearl millet. Some of this research is being done in Georgia. Early results indicate that excellent germplasm for such characters as pest immunity and stiff stalk, not found in cultivated pearl millet accessions, has been transferred to cultivated pearl millet. Interspecific research in the tertiary gene pool is also conducted in Texas and Georgia.

The only enhancement activity involving the wild grassy types has been interspecific hybridization between *P. flaccidum*, *P. orientale*, *P. mezianum* and selected other *Pennisetum* species. Several vigorous interspecific hybrids with improved forage production and winterhardiness have been recovered.

D. **Preservation** - There are some 2500 pearl millet accessions stored at the Southern Regional Plant Introduction Station, Griffin, GA and Coastal Plain Experiment Station, Tifton, GA. There are about 250 subspecies *monodii* and 250 wild *Pennisetum* species accessions stored at Tifton, GA.

Recommendations

Priority of action--Collection of the wild *Pennisetum* species in Africa and South and Central America and evaluation of these wild species and subspecies *monodii* should have priority. Many of the wild species in Africa (center of origin) will be lost if not collected soon. Collection of the wild species may require up to three trips to Africa, two trips to South America and two trips in the Himalayas from Afghanistan to southwest China.

FOXTAIL MILLET, JAPANESE MILLET, AND PROSO MILLET (*Setaria*, *Echinochloa*, and *Panicum*)

D.D. Baltensperger

Millet is a general term for a wide range of small-seeded cereals. The millets of the Gramineae are small-seeded annual grasses including a wide range of cereals that may be used both as grain and for forage. Economically important cultivated millets in the tribe Panicea are pearl millet (covered by W.W. Hanna), foxtail millet (*Setaria italica*), proso millet (*Panicum miliaceum*) and Japanese millet (*Echinocloa frumentaceae*).

The genus *Setaria* is widely distributed in warm and temperate areas. Foxtail millet is the most economically valuable of the genus. Foxtail millet is one of the world's oldest cultivated crops. Its planting has been mentioned in Chinese records as early as 2700 BC. *S. italica* was the most important plant food in the neolithic culture in China, and its domestication and cultivation was the earliest identifiable manifestation of this culture, the beginning of which has been estimated at over 4,000 years ago. In Russia, foxtail millet has been cultivated since ancient times and there is evidence that it was grown as long as 1,500 years ago.

The genus *Echinochloa* is grown for grain and forage in India, eastern Asia and parts of Africa, Australia, and in the eastern USA it has been a valuable forage crop. Japanese and Shama millets *E. frumentacea* or *E. crusgalli, and E. colonum* and Australian millet *E. decompostium* are the primary crops from the genus.

Two Panicum species are important as millets. They are proso millet, *Panicum milliaceum* and Little millet, *Panicum milare*. Proso, an ancient Slav name used in Russia and Poland has also been called common millet, hog millet, broom corn, yellow hog, hershey, and white millet. Although the origin or proso millet has not been ascertained, it is one of the first cultivated cereal grasses, most likely prior to wheat. Proso millet has been known for many thousands of years in eastern Asia including China, India, and Russia. The cultivation of proso is more generally thought to come from central and eastern Asia and spread to India, Russia, the Middle East and Europe. Proso is probably a native of Egypt and Arabia and has been cultivated in Asia Minor and southern Europe since prehistoric times.

Present Germplasm Activities

Germplasm activities with the millets covered above are centered at the USDA Plant Introduction Station, Ames, Iowa; at the University of Nebraska Panhandle Research and Extension Center, Scottsbluff, NE; and to a lesser extent at several land grant institutions around the country. Rick Luman is the curator for the germplasm collection at Ames and David Baltensperger is the breeder working on evaluation and enhancement at Scottsbluff, NE. Primary enhancement objectives include yield, reduced seed shatter, disease and insect resistance, seed size and color. Extensive evaluation has been conducted to identify wheat streak mosaic virus resistant germplasm in foxtail millet to increase its adaptation to the wheat production zones of the Great Plains.

Genetic Vulnerability

The increase in corn acreage in developing countries has led to a rapid decrease in land race germplasm of millets in those countries. Cultivated varieties in the USA are closely related with most released in the past 15 years tracing to one parent within each species.

Germplasm Needs

A. **Collection** - The collection at Ames is deficient in germplasm from communist and former communist countries. China has more than 7,000 samples of foxtail millet many of which may be redundant, but few of which we have. This includes a complete set of monosomic substitution lines, several different types of sterile lines and germplasm adapted to many elevations and rainfall conditions. A strong effort needs to be made to enhance the collections of both *Panicum miliaceum* and *Setaria italica* from China, inner Mongolia, Mongolia, and the southern portion of the former USSR.

   Quarantine - Lines brought to the USA from these regions are required to go through plant quarantine. This process needs to be more timely and more efficient in linkage with plant collection.

B. **Evaluation** - Presently, there is no formal evaluation program in effect. Accessions in the collection are evaluated as needed for characters of interest. Some information is available on some accessions, but much of the germplasm has not been adequately evaluated. A formal, uniform evaluation program is needed to adequately characterize and define the collection.

C. **Enhancement** - Enhancement is currently part of the University of Nebraska program at Scottsbluff, NE. It is limited by collection and evaluation at this time. The primary limitation on foxtail millet production in the High Plains is not actually a serious problem for foxtail millet itself. It is that it serves as a carrier for both the wheat curl mite, the carrier for wheat streak mosaic virus and the virus itself. While adapted cultivars of foxtail are not seriously impacted by the disease, the crop serves as an over-summering host, and adjacent wheat fields are frequently severely impacted. For proso, the main limitations are in seed shattering and shatter-resistant germplasm becomes the highest priority. We are not aware of current enhancement efforts on *Echinocloa*.

D. **Preservation** - The base collection is presently maintained at the North Central Plant Introduction Station at Ames, IO, and its maintenance should be continued at that location. Working collections of a subset of the base collection are maintained at Scottsbluff, NE. Needs for preservation have been outlined as part of the North Carolina Annual Report. With more than 900 accessions of *Panicum* and *Setaria* and more than 200 accessions of *Echinochloa* , this is a major effort.

Recommendations

1. Priority of actions

   a. Collect additional germplasm from communist and former communist countries. Emphasis should be placed on China, former USSR, Mongolia, and inner Mongolia.

   b. Initiate a formal and uniform evaluation of accessions in the collection for cytological, reproductive, agronomic, and physiological traits influencing adaptation, performance, and breeding of respective accessions.

2. Level of support

   a. Support is needed for three collection trips. Each of at least ten days in duration.

   b. Support is needed to get current germplasm collections through plant quarantine.

   c. Support is needed for exchange of germplasm with preservation systems in China.

   d. Support is needed to increase the evaluation effort especially for wheat streak mosaic resistance in foxtail millet.

INDIANGRASS (Sorghastrum)

J.C. Read and K.P. Vogel

There are four main species of *Sorghastrum* that occur in the USA and several other species that occur in other parts of the world. *S. nutans* (L.) Nash (commonly known as indiangrass) is the most wide spread species occurring throughout the USA east of the Rocky Mountains. *S. elliottii* (Mohr) Nash (slender indiangrass) occurs in the 13 southeastern states of the USA and *S. secundum* (Elliott) Nash (lopedsided indiangrass) occurs in South Carolina, Georgia, Alabama, and Florida. *S. apalachicolense* Hall (open indiangrass) occurs only in Florida.

S. nutans has the C4 photosynthetic system and is a tetraploid with 40 chromosomes whereas the other three species are diploid with 20 chromosomes. *S. nutans* is cross-pollinated thus requires some degree of isolation to maintain purity of ecotypes, lines, and cultivars. *S. nutans* is the only indiangrass that is commercially available. It is native to all states east of the Rocky Mountains and was one of the principal grasses of the tallgrass prairie. In the Great Plain states, it is one of the main grasses used in pasture, range, and conservation plantings. Statistics are not available on the number of acres seeded to indiangrass.

There are 11 varieties listed by USDA, but certified seed are available for only six. For two varieties there are no breeders or certified seed available. Varieties have been developed in Oklahoma, Nebraska, New Mexico, Texas, Kansas, Georgia, and Missouri, and the primary intended uses are for range and pasture reseeding, wildlife habitat, surface mine and disturbed site revegetation. If suitable cultivars were developed, this grass could be seeded in mixtures with other grasses on one-third of the land that needs to be revegetated to grasses because of excessive soil erosion in the eastern Great Plains and the Midwest.

Present Germplasm Activities

Limited breeding and germplasm enhancement research on indiangrass is currently being conducted in the USDA-ARS & Nebraska AES cooperative program at Lincoln, NE, and at the Texas A&M University Research and Extension Center at Dallas, TX. Improved germplasm developed at Nebraska can be used in the central Great Plains and the Midwest, and that developed at Dallas can be used in the southern Great Plains. Plant Material Centers of the Natural Resources Conservation Service have also worked with indiangrass. The PMCs collect, evaluate and release the better ecotypes as cultivars in regions that have no adapted cultivar. Currently, the Jimmy Carter Plant Material Center at Americus, GA, in cooperation with the Georgia AES is evaluating indiangrass material for possible release as a new variety. The Lincoln and Dallas programs emphasize breeding for forage yield and forage quality using germplasm adapted to their respective environments. The Lincoln program uses genetic material from a collection made across the north central Great Plains whereas the Dallas program is using a more limited germplasm base collected from north central Texas.

Genetic Vulnerability

Prior to settlement, major areas of the midwestern and Great Plains states of the USA were occupied by the tallgrass prairie. Most of this area has been plowed and is now the primary grain production area of the USA. Less than five percent of the original tallgrass prairie remains in the midwestern states. In the Great Plains area, more extensive areas exist. In 1989, big bluestem was collected from remanent prairie sites in the North Central Region of the USA. The results of this collection indicate that there are numerous small prairie sites scattered throughout the former range of the tallgrass prairie, and that many are in public or conservatory ownership and are preserved. The array and extent of the preserved prairies is such that *in situ* preservation rather than seed storage should be the primary method of germplasm preservation of indiangrass. There are exceptions to this in that the indiangrass germplasm located on privately owned prairies should be collected and preserved.

Information on the location of remnant prairies can be found in the National Heritage databases that are maintained by each state. The Nature Conservancy has assisted states in establishing the databases. The 1989 collections were evaluated in replicated trials at Mead, NE, Ames, IA, and West Lafayette, IN. The results indicate that there are significant differences among germplasm sources for an array of traits.

Indiangrasses are cross-pollinated via wind-blown pollen. Increasing seed of a large number of indiangrass germplasm accessions and maintaining genetic purity of individual accessions requires either a large number of field isolations or a considerable amount of hand labor to bag inflorescences and manually transfer pollen. Field and capitol resources are not available to increase and maintain individual accessions. Maintenance of individual accessions may not even be necessary. The indiangrass germplasm collected from remnant midwestern prairies was classified by the USDA Plant Hardiness Zone of the collection site. Currently, indiangrass plants grown from seed collected from sites in Hardiness Zone 5 are being intermated in a large crossing block. The same procedure is being used for other Hardiness Zones. Seed produced in the crossing blocks will be used to establish a second generation intermating population. Seed produced from the second generation population (Syn 2) will be released as a germplasm composite. The germplasm composite for each Hardiness Zone will be placed in the USDA Germplasm system and will be made available to other breeders.

Several other indiangrass collections have been made at various times in different parts of the USA. These collections were evaluated, and the better accessions were used to develop existing cultivars and experimental strains. The remaining accessions for most of these collections have been lost or discarded because of the difficulty of maintaining genetic purity of this cross-pollinated grass. Released cultivars of indiangrass are primarily improved populations with considerable genetic diversity. The released cultivars are primarily adapted for the Great Plains. Cultivars available for use in many areas of the USA, such as the Midwest, are limited in number and availability. Cultivars of indiangrass are needed for warm-season pastures in many areas of the Midwest and south through Texas.

Germplasm Needs

A. **Collection** - Existing cultivars were developed primarily in the Great Plains and often lack the disease resistance needed in the humid regions of the eastern USA. Systematic collections have been made for the northern Great Plains, but collections from other regions have been less organized and documentation of these collections is nonexistent or difficult to obtain. More importantly, sites of prairies with indiangrass material need to be located and documented as to ownership and condition of the prairie for all regions where indiangrass occurs. There have been very few of the three other species collected and very little is known about these species.

Until breeding programs are in place that can utilize indiangrass germplasm, additional collections are not needed. The network of remnant prairies provides a source of germplasm that can be used by plant breeders when needed. *In situ* preservation can be fully utilized for this species.

B. **Evaluation** - For past collections, data were taken for agronomic traits that could be visually scored on individual plants and ecotypes. Many of these evaluations were done in unreplicated nurseries. Most of the previous collections were discarded after the "best" material was selected from them. The material collected from the northern Great Plains has been evaluated in replicated tests at different locations. The limited amount of germplasm that is in the National Plant Germplasm System has not been evaluated. These accessions and future collections should be evaluated in replicated nurseries at multiple locations over several years for forage yield, seed yield, quality, disease resistance, in monoculture and in mixtures.

C. **Enhancement** - All existing cultivars of indiangrass were selected for adaptation to target environments, forage yield, seed yield, disease resistance, and establishment capability. These grasses are primarily utilized by grazing livestock, but none of the existing cultivars were selected nor evaluated for forage-quality traits. Enhancement and breeding work on improving the forage quality of indiangrass is needed to develop cultivars that can be used in the Midwest and northeastern states for warm-season pastures. Work should concentrate on the above characteristics plus seedling vigor and other seedling characters that enhance stand establishment in pure stands and in mixtures.

D. **Preservation** - Improved methods of increasing PI lines of indiangrass are needed. A limited number of collections are being held by the Plant Introduction System, but they are of limited value because most of them are the products of open-pollinated increase nurseries and, hence, are genetically contaminated. They need to be combined into composites during the next generation of seed increase. Most of the accessions that have been collected in the past have been lost because of the high cost and difficulty of maintaining the genetic purity of individual accessions of these cross-pollinated grasses. Emphasis should be placed on developing populations that are representative of the germplasm of an area rather than on individual plant collections. This approach would greatly increase the efficiency of preserving the genetic diversity of these cross-pollinated grasses by decreasing the number of PI lines that would have to be maintained.

Recommendations

Priority of actions--The USDA National Plant Germplasm System needs to strongly support the National Heritage Program and the associated organizations and governmental units that are maintaining remnant prairie sites. These sites are the best available source of indiangrass germplasm and maintaining *in situ* sites is the most economical method of maintaining genetic diversity because most sites contain dozens of species in addition to indiangrass. Indiangrass germplasm should be systematically collected from the southern Great Plains and the location, condition and ownership of the remnant prairies should be documented. When collections are made, the collected germplasm needs to be thoroughly evaluated in replicated trials for agronomic traits.

The best collections can be used to form elite populations for use by plant breeders. All collections from specific geographic regions, such as the major land resource areas (MLRAs) used in land classification by the NRCS or USDA Hardiness Zones, should be used to form random-mating populations that will be representative of the genetic diversity of each region. These enhanced populations could then be used by any interested breeder as base populations for a breeding program and could also be maintained as seed in the National Plant Introduction System germplasm banks.

It is also important for that germplasm collected from privately controlled prairies, or any prairies that are endangered, be well documented. Documentation on remnant prairies would allow breeders to collect new material at a reduced cost and expense.

ST. AUGUSTINEGRASS (*Stenotaphrum secundatum*)

P. Busey

St. Augustinegrass (*Stenotaphrum secundatum*) is probably native to the Old World, where all its six sibling species are endemic, mainly on islands and coastal areas of the Indian Ocean. The type species of St. Augustinegrass was described in 1788 from South Carolina, within ten years of its first observation in Hawaii, South America, and the Cape of Good Hope. This distribution is consistent with St. Augustinegrass being an Old World native that dispersed in historical times.

Since its introduction as a vegetatively-propagated turfgrass, first recorded in 1880, St. Augustinegrass has become more widely dispersed to coastal settlements, as homogeneous clones. The cold-hardy, shade-tolerant Breviflorus Race includes several cultivars (Seville, Palmetto, Texas Common, Raleigh, Jade, and Delmar) which are diploids ($2n = 18$) and capable of seed production, have moderate genetic variation, and are usable in breeding. They have poor drought avoidance and are always susceptible, to varying degrees, to the southern chinch bug, the main pest of St. Augustinegrass.

There is also a race of African polyploids ($2n = 30$) which produce seed, have little genetic variation, and are usable in breeding. An example is FX-10.

They have good drought avoidance and are occasionally highly resistant to the southern chinch bug, but generally do not tolerate shade. They may represent diploidized introgressants from pembagrass, *Stenotaphrum dimidiatum*. Other polyploids exist, some sterile, such as the important cultivar Floratam ($2n =$ c. 32), as well as triploids ($2n = 27$).

St. Augustinegrass is an important turfgrass because of its competitive, weed-smothering ability in a wide range of soils, and in shady urban habitats, but usually requiring supplemental irrigation. It has better winter growth and color than bermudagrass and bahiagrass, thus it has some potential to enhance winter forage production, particularly in low lying soils. St. Augustinegrass is expanding rapidly as a turf in warm coastal areas around the world, based on the narrow genetic base of vegetatively-propagated cultivars. The naturally occurring genetic variation is much greater than that in cultivation, but the utilization of natural genetic variation is hampered. Much of the existing genetic variation is unsuitable for use as turf, because of weedy tendencies (abundant seedhead production), excessive foliage height, and sterility.

Present Germplasm Activities

Germplasm activities are underway at Texas A & M University, College Station and Dallas; University of Florida, Fort Lauderdale, Gainesville and Belle Glade; Mississippi State University, Mississippi State; and at various commercial companies, including sod farms. For example, the cultivar Palmetto was developed by Sod Solutions, Inc., Mt. Pleasant, South Carolina, in cooperation with Kirkland Sod Farm, New Smyrna Beach, and other sod producers. Resistance screening has recently been documented for chinch bugs, the sting nematode, and drought avoidance. Previous screening has involved salt tolerance, the St. Augustine Decline Strain of Panicum Mosaic Virus (SADV) , shade, and winterhardiness.

Genetic Vulnerability

There has been minimal foreign collection work for St. Augustinegrass. The majority of useful germplasm in the USA is at Land Grant Universities, not in the USDA Plant Germplasm System. Reliance on few vegetatively-propagated cultivars, such as Floratam, has left St. Augustinegrass open to attack by virulent pathogens and chinch bugs.

Germplasm Needs

A. **Collection -** There are several hundred accessions (including hybrids and named cultivars) distributed haphazardly in breeding collections in the USA. Additional germplasm should be collected in East Africa.

B. **Evaluation -** Germplasm is being evaluated for:

   1. Resistance to the southern chinch bug - University of Florida and Texas A & M University.

   2. Winterhardiness - Mississippi State University.

C. **Enhancement -** Germplasm enhancement efforts are underway in both Fort Lauderdale, Belle Glade, Dallas, and at individual sod farms.

D. **Preservation -** Desirable germplasm presently at Fort Lauderdale should be submitted to the National Plant Germplasm System, and so should collections in private hands.

Recommendations

Priority of action--St. Augustinegrass should be collected in East Africa.

Public and private improvement efforts should be coordinated so that more active commercial screening can occur prior to the release of new cultivars, and so that more wild germplasm can be introduced into private breeding efforts.

GAMAGRASSS (*Tripsacum* spp.)

C.L. Dewald

Present Germplasm Activities

The genus *Tripsacum* is distributed through the eastern half of the USA southward to the northern part of South America. Eastern gamagrass, *T. dactyloides*, is the predominant species in the eastern USA. It has potential for use as a grazed or stored forage and a perennial grain crop. It and other species of the genus may also be a source of genes for broadening the genetic base of corn, *Zea mays*. Gamagrasses are robust perennial warm-season bunchgrasses, adapted forms of which have potential to replace annual forage crops such as hybrid sorghums and millets, resulting in lower cultural energy requirements, less soil erosion, and lower production costs. Adapted cultivars should also be useful in reclaiming flood plains and for wildlife.

Germplasm activities are primarily conducted at the USDA-ARS Southern Plains Range Research Station (SPRRS), Woodward, OK, and at several USDA-Natural Resource Conservation Service (NRCS) Plant Material Centers. The NRCS collects, maintains and evaluates *T. dactyloides* at several locations along with breeding work at the Big Flats PMC, Corning, NY. SPRRS maintains a large temperate germplasm nursery, evaluates basic germplasm, and breeds and selects for increased seed and forage production. SPRRS also is actively involved in breeding, genetics, cytogenetics and molecular biology of wide cross hybrids and the transfer of apomixis from *Tripsacum* to maize. Cooperative studies with the University of

Missouri at Columbia to transfer corn rootworm resistance to maize, and with USDA-ARS at Gainesville, FL, to incorporate aerenchyma cell development in maize are underway.

Genetic Vulnerability

Most forms of *Tripsacum* are highly palatable to herbivores and intolerant of stress brought on by overutilization. Therefore, most have been eliminated from native habitats subjected to continuous grazing and are found presently only in protected areas. Many forms have probably been eliminated completely and others are endangered.

Germplasm Needs

A. **Collection** - Germplasm collections are needed from geographic locals where native populations are in jeopardy. Collections from Central and South America should be expanded.

B. **Evaluation** - Accessions in the various collections should be evaluated for important cytogenetic, agronomic, and physiological traits using standard descriptors. This is needed to characterize the variation in present collections and assess the need for additional collections.

C. **Enhancement** - A strong enhancement effort is in progress at SPRRS and the NRCS Plant Material Centers. Efforts are focused on increasing seed production potential and incorporating this trait in adapted productive types. Evaluation and characterization of germplasm should facilitate this effort by identifying specific desirable traits which may be transferred into elite germplasm.

D. **Preservation** - *Tripsacum* spp. are long-lived perennials and may be maintained in living nurseries where they are adapted. Collections maintained at Woodward, OK, and the various NRCS, Plant Materials Centers are fairly representative of *T. dactyloides* in the USA. Tropical germplasm collections representing most of the 16 *Tripsacum* spp are maintained at the USDA-ARS National Clonal Germplasm Repository, Miami, FL, the USDA Tropical Agriculture Research Station, Mayaguez, Puerto Rico, and by CIMMYT near Tlaltizapan, Mexico.

Recommendations

1. Priority of actions

   a. First priority action should be to assure the maintenance of accessions in existing collections. Multiple locations are desirable when the wide adaptation range of Tripsacum is considered.

   b. The second priority action is the initiation of formal systematic evaluation of the accessions using uniform standards.

   c. Third priority action would be collection of additional germplasm from localities where existing materials are threatened including Central and South America.

2. Level of support

   a. Support is needed for maintenance and evaluation of accessions in current collections.

   b. Support is needed to fund collection trips in Central and South America.

ZOYSIAGRASS

M.C. Engelke

Habitats to which *Zoysia* is native range from maritime to montane, and from temperate to equatorial regions of the Pacific Rim. In the 1890s, *Zoysia* was introduced to North America from Japan where its use extends from forage to lawns. It is a warm-season species with excellent turf potential. The genus has nine species. Economically the most significant species include: *Z. japonica, matrella,* and *tenuifolia. Z. japonica* (Japanese Lawngrass) is the most cold tolerant of these species with its natural habitat in the northern climates of China, Japan and Korea. *Z. matrella* (manila grass) posses good cold hardiness but is generally recognized as being finer textured and found frequently in the subtemperate to the subtropical regions of Korea, Japan, southern China and northeastern Australia, Borneo and Papua, New Guinea. Northern Australia is hypothesized as the southern edge of the *Z .matrella* range, where Borneo and New Guinea are near the center of origin.

Z. tenuifolia is noted to be extremely fine textured and is tropical in origin, generally lacking sufficient winterhardiness to survive only in the most southern regions of continental USA. Biologically, other species of importance include *Z. macrostaycha, and sinica.* Both are noted to have excellent winterhardiness and also good-excellent tolerance to poor-quality soils and saline conditions. Herbarium specimens, representing much of the range of the *Zoysia* support the hypothesis that up to nine species exist. However, certain taxa are under collected. Under represented taxa include *Z. seslerioides* and *Z. minima* and to a lesser extent *Z. matrella.* Specimens of *Z. seslerioides* were collected from Vietnam, and *Z. minima* collections are limited to New Zealand. There are no known living specimens of *Z. seslerioides or Z. minima* among the germplasm collections presently held in the USA.

Present Germplasm Activities

An active breeding and germplasm enhancement research effort on zoysiagrass is being funded by the USA Golf Association and conducted at Texas A&M Research and Extension Center, at Dallas, TX. The program previously being conducted by the USA Department of Agriculture - Beltsville, MD, was discontinued in 1988 with the medical retirement of the scientist in charge. There are two significant efforts within the private sector targeted to improvement of zoysiagrasses, one located in southern Texas - previously in Florida, and the second in the Pacific Northwest region. The latter has a primary objective of developing seeded zoysiagrasses for the USA.

Genetic Variability

At present, the largest single collection of zoysiagrass germplasm is held by Texas A&M University - Dallas, TX, as part of the breeding program. This collection numbers approximately 1000 unique accessions obtained through collection trips and exchanges from Japan, Korea, Taiwan, Philippines, China, New Zealand and Australia, and represents specimens from *Z. macrostaycha, sinica, japonica, matrella and tenuifolia.* The *Zoysia* genus is distributed from 50 ^{o} N latitude to 35 ^{o} S latitude and has a broad range of biological traits which enhances this extensive range adaptability. Zoysiagrass germplasm is more vulnerable than was once thought as the range of diseases and insects which target this grass are becoming more prevalent. The increase in virulent pests is expected to rise as more of the grasses are utilized in more diverse climatic conditions as turf. Nematodes have restricted the zoysiagrasses from use in the lighter soils of the southern USA with no substantiated source of resistance available for development. Most commercially available cultivars are presently vegetatively propagated which further adds to the genetic vulnerability of the species. The vulnerability of this species is also compounded by the rapid decimation of its natural habitat of China and developing areas of other Pacific Rim Countries due to population shifts and increases.

Germplasm Needs

A. **Collection** - At present the zoysiagrass germplasm resources broadly represent the diversity of the *Z. japonica* species, however, additional resources of the other species and other regions of the world where zoysiagrasses are indigenous need to be collected. Specifically, northeastern Australia, Borneo and Papua New Guinea, as well as Vietnam, and southeast Asia.

B. **Evaluation** - Extensive evaluations have been made among existing accessions in the germplasm introduction nursery specifically for agronomic and biological traits impacting preservation and performance under natural environmental conditions. Specific evaluation tests have and are being conducted on root growth characters, low light tolerance, salinity, disease and insect response, recuperative and reproductive capability.

C. **Enhancement** - The germplasm collection being assembled since 1982 has served as the primary source of germplasm leading to the release of four zoysiagrass cultivars in 1996 from Texas A&M, as well as the private release of additional seeded and vegetative cultivars which directly link to the former USDA program under the supervision of Dr. Jack Murray. Work continues on the resource base with emphasis on identifying specific genes for resistance to insects and diseases, as well as rhizome production, salinity tolerance and tolerance to low-light conditions. Efforts are also underway in various programs to develop seeded zoysiagrasses. This latter effort is confined primarily to the *Z. japonica* and larger seeded species of *Zoysia*, most of which are also identified for more northerly adaptation.

D. **Preservation -** *Zoysia spp* are readily propagated vegetatively as they possess both rhizomes and stolons. The initial collection assembled in 1982 and added to over the years is continually maintained under greenhouse conditions at Texas A&M University at Dallas, TX. Simultaneously, this collection has been laboratory, greenhouse and field evaluated. However, the only material considered to be preserved relative to genetic integrity is the greenhouse collection. Other collections are most likely being maintained by interested developmental programs.

Recommendations

This germplasm, as well as breeder stock of the many vegetatively-propagated turf and ornamental plants require special attention to provide long-term preservation and maintenance of this limited resource. It is considered to be of very high priority that an independent and fully funded vegetative germplasm repository be established as soon as possible. There is no way to recover the original breeder stock of early releases of many of the bermudagrasses, or earlier zoysiagrasses or similar species. From an academic as well as economic necessity, the ability to recover the exact variety is as important for these vegetatively-propagated species as it is for the seed-propagated species for which the National Seed Laboratory was developed.

Priority of actions--Additional plant collection and survey trips are needed to develop a broader genetic base and to add to the passport information needed to further understand the distribution, phylogeny and preservation of this species. Specifically, additional collection trips need to be made into northeastern China to assemble *Z. japonica and matrella* accessions from an area which is being rapidly urbanized and forever devoid of native stands. Collections need to also be assembled from throughout southeast Asia where a preponderance of *Z. tenuifolia and matrella* have evolved, as well as into northern Australia, New Zealand, Borneo and New Guinea to expand the germplasm resources with the additional of other species. Additional support is needed to evaluate the existing and new zoysiagrass germplasm resources for nematode and mite resistance, seed production potential and taxonomic studies on the phylogeny of this economically important warm-season grass.

MISCELLANEOUS WARM-SEASON GRASSES
(Bouteloua, Hemarthria, Digitaria, Sporobolus, Schizachyrium)

M.A. Hussey, P.W. Voigt, S.C. Schank, and D.R. Huff

The gramagrasses consist of about 40 species native to the Americas. Three species are of primary importance in the USA Sideoats grama, *Bouteloua curtipendula*, is found throughout most of the USA east of the Rocky Mountains and in the arid southwest. It is of greatest importance in the central and southern Great Plains. Most of the germplasm found in that area is rhizomatous, tetraploid in chromosome number (2n=4x=40), sexual, photoperiod sensitive, and can be referred to *B. curtipendula* var. *curtipendula.* Sideoats grama found in the southwest, *B. curtiepndula* var. *caespitosa*, lacks rhizomes, is aneuploid (2n=85 to 101), apomictic, and responds relatively uniformly to photoperiod. The two varieties are relatively well isolated. Limited attempts at hybridization have not been successful. Blue grama, *Bouteloua qracilis*, is almost as widely distributed in the USA as sideoats grama but may be more important because of its role as the predominant warm-season grass in much of the short-grass region from Texas to Canada. Black grama, *Bouteloua eriopoda*, although not widely distributed in the USA, is a major grass of the desert grasslands of the southwest.

Present Germplasm Activities

Germplasm activities with Bouteloua species are limited primarily to collection and selection efforts within the USDA-NRCS.

Genetic Vulnerability

In general, the *Boutelouas* are not considered vulnerable. Vast expanses of rangeland containing sideoats grama and blue grama remain and are available for germplasm collection if needed. Twelve cultivars of sideoats grama have been released over the years of which nine remain in at least limited commercial production. Only two blue grama cultivars, both for the southern Great Plains, have been released. Black grama is more vulnerable than the other two because of the combined effects of overgrazing, drought, and invasion of brush. However, two cultivars have been released and are available for revegetation needs.

Germplasm Needs

A. **Collection -** Collections of blue gramas appear adequate. Although the amount of germplasm maintained in the PI system is minimal, the extensive wild stands found on rangelands provide an adequate supply of germplasm for future needs. However, efforts to obtain germplasm from Mexico could be worthwhile. Black grama stands should be carefully monitored to determine if a future intensive collection effort might be necessary to preserve genetic diversity.

B. **Evaluation -** The limited number of projects currently underway appear to meet the needs for this genus. Most are of minor regional importance and have limited potential for economic impact.

C. **Enhancement -**

D. **Preservation -** Current preservation efforts at the Southern Regional Plant Introduction Station are probably adequate as long as the wild stands of grama grasses are not endangered.

Recommendations

Present efforts appear adequate to the need. Although numerous interesting projects could be developed with the gramas, on a national and international basis other warm-season grasses have greater potential for economic impact in semiarid and arid regions. Proposals for gramagrass germplasm research might better be supported by state or private conservation organizations.

The genus *Hemarthria* is a forage grass adapted to wet areas in the tropics and sub-tropics. The common name, limpograss, was given to *H. altissima* as varieties were released in the 1970s. Introductions of *H. altissima* from Dr. A. J. Oakes' collection trip in 1964 were highly successful in some of the wetter or specialized sites in Florida; and as a result, three new cultivars were released in 1978, i.e., cv. Redalta, cv. Greenalta, and cv. Bigalta limpograss. Additional germplasm of *Hemarthria* was obtained and in 1984, an improved variety, cv. Floralta limpograss, was released. The limpograsses can survive inundation for several consecutive months, and have a minor, but important, ecological niche in Florida.

Present Germplasm Activities

The major center of genetic improvement of *Hemarthria* has been the University of Florida at Gainesville, FL. No current USDA-ARS or SAES program is working with this genus.

Genetic Vulnerability

Hemarthrias are diploid, tetraploid and hexaploid. Efforts to create a triploid have not been successful. Since the limpograsses are mostly propagated vegetatively, they are particularly vulnerable to genetic problems which can arise when a single genotype is used.

Germplasm Needs

A. **Collection -**

B. **Evaluation -**

C. **Enhancement -**

D. **Preservation -** Seed of the *Hemarthrias* in the USA is stored at the Southern Regional Plant Introduction Station in Experiment, GA. Foundation seed fields of the released cultivars are maintained at Gainesville and Brooksville, FL. All *Hemarthrias* at Gainesville are maintained in vegetative form.

Recommendations

Priority of action--The previous collection trips, the seed exchanges and the breeding program at Florida have created sufficient new cultivars, and hence, no additional improvements are foreseen for this species in the next decade.

The genus *Digitaria* contains primarily tropical or subtropical warm-season grasses. Depending upon the taxonomist, the number of species ranges from 35 to 315. The best known exception to the sub-tropical adaptation area is *D. sanquinalis* and *D. adscendens*, commonly known as crab grass, a weed which occupies many temperate and even sub-arctic areas. Crab grass is an annual and a prolific seeder, producing an estimated

125,000 seeds from a single plant. Other weedy species also occur which infest coffee fields in Brazil.

One selection of crab grass, cv. Red River has been released in the USA for use as a companion crop with wheat grazing systems while several improved cultivars of digitgrass are well known in the tropics.

Pangolagrass, *D. decumbens* L. Stent., is known for its high-quality forage and has been planted on millions of hectares throughout the tropics and subtropics. Other related varieties of digitgrass are cv. Slenderstem, cv. Taiwan, cv. Transvala, cv. Survenola, and a Hawaiian cultivar.

Present Germplasm Activities

Centers of improvement of *Digitaria* have been the University of Florida at Gainesville, the Hawaiian Agricultural Experiment Station at Honolulu, and CSIRO at Brisbane, Australia. At the present time, with at least six released cultivars already available, the breeding programs at these three locations have diminished. The higher nitrogen fertilizer requirements of digitgrass and the lack of a seed-propagated cultivar have caused the decline in interest in the digitgrasses during the past decade.

Genetic Vulnerability

The majority of digitgrasses are perennial and have ploidy levels of 2x, 3x, 4x, 5x, 6x, and 8x. The triploids are completely sterile (sexually), and only limited seed production is obtained from most of the other perennial species. Wide interspecific crosses were made from 1961 to 1980 because of the genetic vulnerability of pangolagrass, which was a triploid cultivar, and of only one genotype worldwide. In the 1960s, a devastating disease of pangolagrass was reported in Surinam and later described in Fiji, Guyana and Brazil. Fear that the virus would spread to the USA and to approximately 500,000 acres of pangolagrass in Florida sparked intense internationally-involved breeding programs. Breeding objectives were met, and new cultivars were released which had resistance to Pangola Stunt Virus (PSV).

Germplasm Needs

A. **Collection** - Due to two extensive plant collection trips by A. J. Oakes into the native habitats of Africa and a very cooperative seed exchange of diverse germplasm, the breeding objectives in *Digitaria* have largely been met. No future collection trips for this genus are foreseen as needed in the next decade.

B. **Evaluation** - Data on the six released cultivars of digitgrass are contained in the release circulars of Pangola, Slenderstem, Taiwan, Transvala, Survenola, and the Hawaiian variety. Advancements in forage quality, disease resistance, and winterhardiness of the genus were made and documented. Distribution of *Digitaria* sp. in Africa and limited evaluation research suggests that some *Digitaria* germplasm is adapted to drier environments. Some *Digitaria* germplasm is also moderately winterhardy. A project to evaluate the adaptation of *Digitaria* germplasm to environments of 20- to 35-inch annual precipitation and 5° to 15°F minimum annual temperature would be of value.

C. **Enhancement** - Most of the enhancement achieved came by interspecific hybridization of selected genotypes of *Digitaria*. No additional enhancement of germplasm is deemed necessary at this time.

D. **Preservation** - Seed of the *Digitarias* in the USA is stored at the Southern Regional Plant Introduction Station, Experiment, GA. Foundation seed fields of the released cultivars Transvala and Survenola are maintained at Gainesville, FL.

Recommendations

Priority of action--The previous collection trips and the extensive breeding programs on *Digitarias* have met the immediate needs in warm-humid environments. Evaluation research is needed in colder and more arid environments.

The genus *Sporobolus* contains about 150 species, none of which are of worldwide importance. The genus is of some importance in the Great Plains and desert grasslands of North America. Most Sporobolus species in the USA are commonly referred to as dropseeds, but two of the more important are called sacatons. Sand dropseed, *S. cryptandus*, a polymorphic species complex, is widely distributed in the USA but is most important in the Great Plains and southwest. It is believed to be largely self-pollinated. Other dropseeds of forage importance, e. g., spike, *S. contractus*, giant, *S. giganteus*, and mesa dropseed, *S. flexuosus*, are restricted primarily to the southwest. Alkali sacaton, *S. airoides* is found throughout most of the western USA and Mexico. It and the closely related big sacaton, *S. wrightii*, are important because of their adaptation to deep, moderately fine-textured saline, saline alkali, and alkali soils. Because of this adaptation to sites that can receive "run off" moisture and because of their high-forage yield capacity, the sacatons have high potential for economic impact.

Present Germplasm Activities

Germplasm activities with *Sporobolus* species are limited to collection and evaluation efforts by the USDA-NRCS.

Genetic Vulnerability

The dropseeds cannot be considered vulnerable. Rangelands contain ample germplasm should need for collection develop. Likewise, alkali sacaton is widely dispersed and its germplasm is not in danger. The distribution of big sacaton is more limited. Many stands in Arizona have been eliminated by overgrazing, erosion that lowered water tables, and development. Germplasm from threatened areas in the USA and in Mexico should be collected and preserved for future use.

Germplasm Needs

A. **Collection** - The *Sporobolus* germplasm stored at the Western Plant Introduction Station, Pullman, WA, is very limited. This is not a serious problem because existing rangelands contain ample germplasm for most species of importance. A possible exception is big sacaton. Some potentially important germplasm has already been lost. An effort to collect seed from stands threatened by erosion or development is needed. Each population sampled should be increased, when necessary, in isolation to prevent pollination by other populations. A full-scale collection effort for big sacaton in the southwestern USA and Mexico should be undertaken sometime in the near future to provide germplasm for needed evaluation and enhancement research.

B. **Evaluation** - Additional evaluation research is needed only for big sacaton. Work to determine the relationship between alkali and big sacaton would also be important.

C. **Enhancement** - Enhancement research is needed for big sacaton. Characteristics requiring improvement include seed yield, plant establishment, and forage quality. Of these characters, improved plant establishment is the most critical.

D. **Preservation** - Current efforts with existing collections are adequate. However, additional efforts will be needed if the necessary increase in germplasm activities is undertaken. While the Western Plant Introduction Station could probably continue to handle increase and preservation of this germplasm, it would seem more logical for the increase effort to be located within the region of adaptation of big sacaton.

Recommendations

Additional efforts with the dropseeds are probably not needed at this time. However, a significant new effort with a grass native to American, big sacaton, is needed.

Little bluestem [*Schizachyrium scoparium* (Michx.) Nash var. *scoparium* (formerly *Andropogon scoparius*)] is a native, warm-season, perennial bunchgrass that ranges throughout much of central and eastern North America, from Canada to Mexico (Hitchcock, 1951; Archer and Bunch, 1953; Wipff, 1996). It is considered a climax species in the grassland biome of the central plains and southern prairies (Hartley, 1964; Gould, 1968), but in the eastern temperate forest biome it is a successional species on disturbed sites and along roadsides (Bard, 1952; Roos and Quinn, 1977). Little bluestem is highly polymorphic throughout its range which is likely enhanced by its outbreeding and cross-pollinated mode of reproduction (Anderson and Aldous, 1938; Wipff, 1996).

Once a dominant component of the central Great Plains, little bluestem has long been used for revegetation and conservation purposes to stabilize soils from wind and water erosion. As a native species, it is increasingly being used for restoration projects to enhance the biodiveristy of locally disturbed sites. Little is known, however, concerning the genetic diversity and variability of the species in general, let alone among populations within a region. Wipff (1996) suggests that the morphological features of little bluestem vary independently and continuously across its range, and that attempts to classify the species on a regional scale have proven to be unworkable.

Present Germplasm Activities

Most work historically has been collection of local ecotypes and increase of seed of desirable types. Most of the cultivars released came from the central Great Plains and the southern/southwest Great Plains. Little work is underway in the USA at present to collect and improve little bluestem. Some work is being done to characterize genetic variability. In one study at Pennsylvania State University to compare genetic variation within and among four populations of little bluestem, genotypes were collected from high and low fertility sites in both New Jersey, a forested biome, and in Oklahoma, a grassland biome. Most genetic variation resided within populations, but significant differences were detected between sites within each biome. In this wide-ranging and highly variable species, molecular marker analysis suggested that extreme local site differences in fertility and ecological history promote genetic differentiation equal to or greater than geographic differentiation.

In a transplant garden in Texas, McMillan (1969) showed that little bluestem from northern and eastern North American sites did not persist, and only the materials from central and eastern Texas and from Mexico survived four years after termination of weeding and watering. In addition, Obee (1995) reported marked differences in phenology, biomass allocation, and lifehistory strategies between Oklahoma and New Jersey populations.

Status of Crop Vulnerability

There are only 37 accessions of little bluestem listed in GRIN. Of these, 13 are of released cultivars, some of which are duplicated. Larger collections from the southern Great Plains and the Northern Great Plains that have been done largely by the NRCS were not entered in the NPGS and are probably lost for preservation purposes. Sixty-eight of the accessions collected in the 1980s from the Northern Great Plains were combined into the cultivar Badlands. No accessions are available from the northeast, southeast, and from Canada.

Germplasm Needs

A. **Collection -** Previous collections should be characterized and data entered into GRIN. A detailed study of accession representation across the range of adaptation needs to be undertaken, then domestic collection trips planned to fill holes where local ecotypes have not been collected.

B. **Evaluation -** This species has great potential for reclamation and landscapes requiring "genetically local" types. The diversity needs to be further characterized.

C. **Enhancement -** Because of the considerable genetic diversity that is apparent in little bluestem, enhancement activities may remain as seed increase of locally adapted ecotypes for the near future. Genetic recombination by breeding should be initiated for areas where local ecotypes are not available.

D. **Preservation -** Attempts should be made to ensure that the genetic diversity that has been collected in the past be entered into the NPGS and seed preserved at NSSL.

Recommendations

Continue present work to characterize genetic variation, determine areas further collection is needed, and prepare collection trips to acquire the necessary germplasm to represent the diversity of this important native North American grass. Seed sources for little bluestem in restoration/revegetation should not only be local but sitespecific, e.g., high vs low fertility, especially if specific goals are the maintenance of local genetic integrity and/or local adaptation.

Management recommendations for seed transfer should be based on a combination of genetic markers and quantitative traits, particularly phenological development in relation to the local environment. A native grass population is more than just a latin binomial; evolutionary forces often create something unique and irreplaceable at the local level.

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