veloped in Montana may make that species more desirable. At Mandan, we are collecting surviving plants of birdsfoot trefoil to improve its hardiness and drought tolerance. Birdsfoot trefoil, Cicer, and sainfoin do not cause bloat. Yellow-flowered alfalfa apparently does not have as great a tendency to cause bloat as do purple varieties.

What then are the possibilities for an improved range legume? They are better than ever before. Breeders are exchanging germplasm and conducting cooperative tests. When we began our program at Mandan, we received breeding material from Colorado that had undergone three cycles of intercrossing. This material consisted of 63 lines of variegated and yellow-flowered alfalfa that various breeders had judged the most suitable for range purposes. We are using this as the basis of some of our breeding work. Colorado, Utah and Mandan are planning a cooperative test of alfalfas containing varying amounts of yellow-flowered germplasm from our old plantings. The new methods and machinery for sod-seeding, such as those being tested at Dickinson, ND, suggest the possibility of improved initial establishment of range legumes.

Because of the high cost of nitrogen fertilizers, scientists at Minnesota and Mandan are looking more closely at the mechanism of nitrification by legumes and are trying to evaluate how much of the fixed nitrogen may be available for use by associated vegetation. Results from this renewed interest in legumes for pasture and rangeland should better document the benefits and type of legumes best suited for this use.

Genetic Improvement of Forage Grasses

J. D. Berdahl and R. E. Barker

Grass breeding at the Northern Great Plains Research Center is directed toward species useful for range, pasture, hay, and other specialized needs. Our primary objective is development of new grass cultivars with improved capability for stand establishment and sustained production of high quality forage under diverse growing conditions. Expertise of plant physiologists, plant pathologists, animal nutritionists, soil scientists, range and pasture management specialists, and others is needed to make maximum progress in breeding forage grasses.

Forage grass breeding was initiated at the Northern Great Plains Research Center, Mandan, ND, by the USDA in 1936 (5). Grass cultivars that have resulted from this breeding program include "Nordan" crested wheatgrass, "Vinall" Russian wildrye, "Green Stipagrass" and "Lodorm" green needlegrass, "Mandan Wildrye" (Canada wildrye), and "Mandan Ricegrass" (a hybrid between green needlegrass and Indian ricegrass). In addition, the USDA Soil Conservation Service has used several advanced strains of grasses from the Mandan program in range and pasture improvement programs in the northern Great Plains.

Grass improvement efforts are directed toward species useful for range, pasture and hay. Grasses are also being bred for such specialized uses as mined-land reclamation and barriers for improved snow distribution on cultivated lands. Production of high-yielding, high-quality forage for different purposes and under diverse environmental conditions requires the use of both native and naturalized (introduced) species. No single grass species can fulfill all our needs. Breeding is currently under way on crested wheatgrass, western wheatgrass, Russian wildrye, blue grama, intermediate wheatgrass, and orchardgrass.

In addition to the breeding work, many other grass species and interspecific hybrids are being evaluated in field performance tests. Table 1 gives a summary of average annual forage yields at Mandan for several grass species grown under different management systems. The yields presented are means of all cultivars included in performance tests for the given species.

Choice of Species

Productive forage breeding programs are costly and time-consuming, so breeding must be concentrated on species that meet critical needs and have potential for

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improvement. We are directing our breeding efforts on crested wheatgrass, western wheatgrass, and Russian wildrye to help meet needs for new cool-season cultivars on rangeland. Crested wheatgrass provides early-season grazing, and Russian wildrye provides high quality grass for both summer and extended fall grazing. Western wheatgrass, particularly late-maturing cultivars, would help provide adequate forage for midseason grazing. A species evaluation test on strip-mined rangeland has shown that crested and western wheatgrass and Russian wildrye are valuable grasses for mined-land reclamation (1).

A warm-season grass complements cool-season species in maintaining high productivity on rangeland throughout the grazing season. The number of warm-season grasses available for the northern Great Plains is limited. Blue grama, the predominant warm-season species on native range, is a logical choice for breeding work. However, stand establishment of blue grama without supplemental water is extremely difficult. An extensive breeding effort on this species will not be made until we determine the genetic potential for improving seedling vigor under conditions of water stress.

Currently, our breeding efforts are concentrated on intermediate wheatgrass and orchardgrass for irrigated pasture and hayland and for areas where drought is usually not severe. We need forage grasses genetically adapted to land that has high potential productivity. Intermediate wheatgrass, which taxonomically includes pubescent wheatgrass, has high yields in either pure stands or grass-legume mixtures and is well suited for crop rotations that include forage grasses. Under heavy use, persistence in intermediate wheatgrass in the northern Great Plains has been a problem. However, the huge geographic distribution of intermediate wheatgrass in the USSR has not been adequately sampled. We are optimistic that recent introductions of intermediate wheatgrass from cold and dry climatic areas in the USSR may have good persistence.

Orchardgrass has excellent regrowth potential under irrigation, but existing cultivars lack sufficient winterhardiness to be grown in pure stands. Preliminary field tests at Mandan show that recent introductions from Turkey and the USSR have higher levels of winterhardiness than existing cultivars. Breeding efforts on orchardgrass will be expanded if germplasm that has adequate winterhardiness for the northern Great Plains is identified.

Smooth bromegrass and reed canarygrass have good potential for areas with adequate soil moisture. Neighboring states and Canadian provinces have productive breeding programs for these two grasses, and Mandan is presently confining work on smooth brome and reed canarygrass to performance testing.

Forage grasses have a number of specialized uses, and a limited breeding effort is being made at Mandan to produce cultivars that are uniquely suited to special needs. For example, the interspecific hybrid between Altai wildrye and basin wildrye has a thick stem and coarse leaves and can produce tall, rank growth under dry conditions. A source population of this material has been established, and selection will be made for nonrhizomatous plants that would be suited for either grass barrier strips in cultivated fields or habitats for game birds.

Establishment of Source Populations

Genetic variability must be available in a species before a plant breeder can improve any character. For this reason, we have emphasized assembling source populations of grass species that contain a wide range of genetic diversity. For example, the Bismarck Plant Materials Center (Soil Conservation Service) and the Northern Great Plains Research Center at Mandan (Science and Education Administration, Federal Research — formerly the Agricultural Research Service) are cooperating to establish source populations of western wheatgrass and blue grama.

Vegetative samples have been systematically collected at 1,035 range sites in western North Dakota and South Dakota by the SCS to provide a total of 5,175 samples of each of the two grasses. The forage breeding project at Mandan propogated two ramets (vegetative cuttings) in the greenhouse from each of the 10,350 samples (Figure 1). Space-planted nurseries containing over 10,000 plants of each species will be established in the field in the spring of 1978 and will provide a gene base for breeding efforts. This is the largest and most intensive collection of these two native grass species in existence and is an excellent example of cooperative efforts between the Soil Conservation Service and the Federal Research branch of the Science and Education Administration.

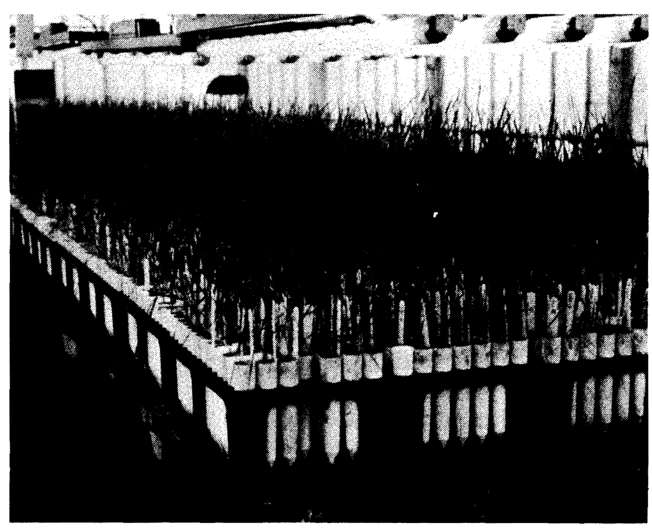

Figure 1. Preparation of western wheatgrass plants for transplanting to a field breeding nursery.

The forage breeding project at Mandan also has established large source populations of crested and intermediate wheatgrasses, Russian wildrye, and orchardgrass. New genetic material of these grass species is observed in space-planted nurseries as it becomes available from plant introductions, domestic collections, and other grass breeding programs (Figure 2). Source nurseries in 1978 will contain about 50,000 spaced plants that will receive preliminary evaluation for agronomic type and adaptation to the northern Great Plains.

Figure 2. Breeding nursery of intermediate wheatgrass.

Breeding Objectives

Lack of soil water in the northern Great Plains often puts severe limits on forage yield, regardless of the genetic constitution of a particular grass cultivar. For rangeland grasses our primary breeding objective is dependability. Dependability, a general objective, is made up of specific components of which the more important are: 1) stand establishment, 2) persistence, and 3) production.

A dependable grass can establish itself in a stand under conditions that are less than ideal. Harlan (4) concluded that no grass species or cultivar will be marketed extensively in the Great Plains unless it can be readily propagated. Seed size is a highly heritable character that is related to seedling vigor and stand establishment. At Mandan, emergence from vermiculite maintained at 6.0 bars of water tension was much more rapid and complete for large seed of Russian wildrye than for small (Figure 3). In addition to improved stand establishment, another obvious advantage of large seed size is improved seed handling characteristics. Other morphological and physiological factors such as coleoptile length, root development, and growth rate are also related to stand establishment.

The cost of reestablishment, the need for a consistent supply of forage, and erosion hazards make persistence an absolutely essential character for rangeland grasses. Persistence is a complex character that is related to a plant's innate ability to accumulate food reserves, resist disease, and tolerate or escape water, heat, or cold stress.

Dependable grasses have the potential to produce under both the favorable and adverse growing conditions associated with rangeland. We must strive to develop cultivars that make more efficient use of water, soil nutrients, light, CO_2, and temperature. Different grass species have unique growth characteristics, and often more than one species is needed to help maintain a consistent supply of forage.

Breeding objectives are different for forage grasses grown on land with high productivity, such as irrigated land. Here, high yield potential must be the primary consideration so that grass or grass-legume mixtures can compete economically with other crops. Also, disease resistance is usually critical when moisture is in adequate supply. As with rangeland, persistence is essential to eliminate the cost and inconvenience of reestablishment.

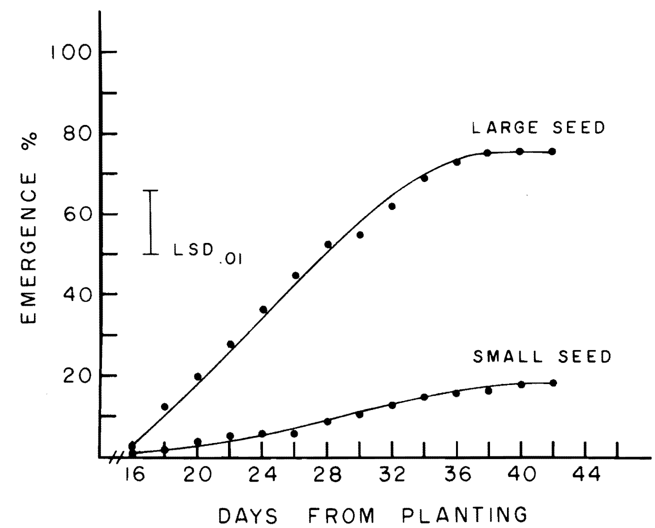

Figure 3. Seedling emergence from small and large Russian wildrye seed planted 5.0 cm deep in vermiculite maintained at 6.0 bars of water tension.

Multidisciplinary Approach is Needed

The previous discussion of breeding objectives shows that a forage breeder must rely on the expertise of scientists from other disciplines to make maximum progress. Hanway (3) states that a plant breeder is but one component of a large, integrated, comprehensive crop-development team. Burton (2) elaborates on teamwork in crop development and points out that rate of genetic improvement depends largely on the capacity and precision of screening techniques. Plant physiologists, plant pathologists, soil scientists, range and pasture management specialists, animal nutritionists, and others can identify both the strengths and weaknesses of a particular grass species and can develop specific techniques for selecting superior plants. The grass breeder must use these screening techniques developed by other scientists to improve the genetic makeup of a particular species.

Conclusions

Development of superior forage grass cultivars is a long-term effort. Selection for both forage and seed production in perennial species requires several years for evaluation of a single generation. Most perennial grasses are cross-pollinated rather than self-pollinated, which complicates breeding methodology. Livestock (primarily cattle) are the ultimate consumers of grass, so grazing and feeding trials are necessary to evaluate the value of potential new cultivars.

Most would agree that improved grass cultivars coupled with more efficient management of grasslands are vital in supplying current and future demands for livestock products. Potential dividends from investment in grass improvement are high.

Table 1. Dry matter forage yields of grasses grown at Mandan, ND.

		Species					
Year	Management	Crested Wheatgrass	Russian Wildrye	Intermediate Wheatgrass	Western Wheatgrass	Reed Canarygrass	Orchardgrass
	Irrigated	ton/acre					
1974	Hay	2.85(1)[1]	0.43(1)	2.75(1)		1.09(1)	
1975	Hay	2.44(1)	1.75(2)	3.01(1)		2.38(1)	
	Pasture	2.62(2)	1.97(3)	3.08(2)		2.84(2)	
1976	Hay	1.66(1)	0.89(1)	1.42(1)		1.31(1)	1.27(1)
1977	Hay	1.65(1)	0.90(1)	2.19(1)		1.62(1)	
	Dryland						
1974	Hay	1.71(1)	0.24(1)	0.87(1)	0.31(1)		
1975	Hay	1.98(1)	1.56(2)	1.89(1)	1.71(1)		
	Pasture	1.95(2)	1.60(2)	0.70(1)	1.71(2)		
1976	Hay	1.24(1)	0.60(1)	0.87(1)	0.46(1)		
1977	Hay	0.46(1)	0.29(1)	[2]	0.31(1)		

[1]*Numbers in parentheses refer to number of cuts.*
[2]*Not harvested due to severe drought.*

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