ESTABLISHMENT OF SEEDED GRASSLANDS FOR WILDLIFE HABITAT IN THE PRAIRIE POTHOLE REGION

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Abstract

Techniques are described for establishment of seeded grasslands on cultivated soils to provide wildlife habitat within the glaciated prairie pothole region in the north-central United States. Management of grassland habitats on a sound ecological basis is an important wildlife management activity in the region. The primary purpose of the guidelines in this publication is to help managers establish and maintain good stands of seeded cover for waterfowl nesting and use by other prairie wildlife. Several options are available for selecting a type of cover to be established. The following seeded grassland types are described: (1) introduced cool-season grasses and legumes; (2) tall, warm-season native grasses; and (3) mixed-grass prairie grasses. Major vegetative species recommended for (1) are tall wheatgrass *(Agropyron elongatum)*, intermediate wheatgrass *(A. intermedium)*, alfalfa *(Medicago sativa)*, and sweetclover *(Melilotus spp.)*; for (2) are big bluestem *(Andropogon gerardi)*, indiangrass *(Sorghastrum nutans)*, and switchgrass *(Panicum virgatum)*; for (3) are green needlegrass *(Stipa viridula)*, little bluestem *(Andropogon scoparius)*, western wheatgrass *(Agropyron smithii)*, and sideoats grama *(Bouteloua curtipendula)*. Important factors that affect the success of establishment of seeded grasslands include site adaptability, site preparation, seedbed preparation, planting equipment and methods, rates and dates of seeding, and seed sources. A management goal for seeded grasslands intended to provide optimum habitat for dabbling duck nesting should be to maintain vigorous stands of vegetation with the tallest, most dense cover form that is possible under prevailing soil and climatic conditions. Grassland management is a never-ending job and seeded grasslands require periodic rejuvenation to maintain them in an optimum condition. Prescribed burning and planned grazing systems are acceptable methods for periodically rejuvenating seeded native grasses. Stands of introduced grasses and legumes are best maintained by mechanical tillages; reseeding is often necessary after 1 or 2 years of grain farming. The need for good management of all areas dedicated to wildlife habitat is emphasized by the rate of destruction and degradation of grassland habitats. Desirable wildlife populations can be benefited by establishment and maintenance of high-quality stands of seeded grasslands.

Habitat management is one of the most basic and practical activities employed in wildlife management. Management of grassland habitat is an integral part of wildlife programs that influence the distribution and production of game species in the prairie pothole region. Man's activities have often been detrimental to wildlife but some species are highly responsive to the establishment of new habitat. The purpose of this publication is to help land managers establish and maintain good stands of seeded grasslands for waterfowl nesting and use by other prairie wildlife. Figure 1 shows the area of applicability for these grassland establishment guidelines (U.S. Department of Agriculture, Soil Conservation Service [USDA-SCS] 1978*a*).

The 300,000-square-mile glaciated prairie pothole region was originally a magnificent area of extensive native grasslands containing millions of wetlands. Diverse and abundant populations of mammals and birds inhabited this area in association with natural plant communities. Following occupation of the land by European man, the area was drastically modified and its suitability for waterfowl production is now greatly reduced in many areas (Fig. 2). Cultivation and crop production have eliminated nearly all natural vegetation on thousands of square miles and overgrazing has reduced the quality of many remaining native grasslands. Studies have indicated duck production to be low in intensively farmed agricultural regions of the prairie pothole region (Milonski 1958; Higgins 1977). Preservation and management of public and private lands by State and Federal agencies are needed to increase production of waterfowl and other prairie wildlife (Fig. 3).

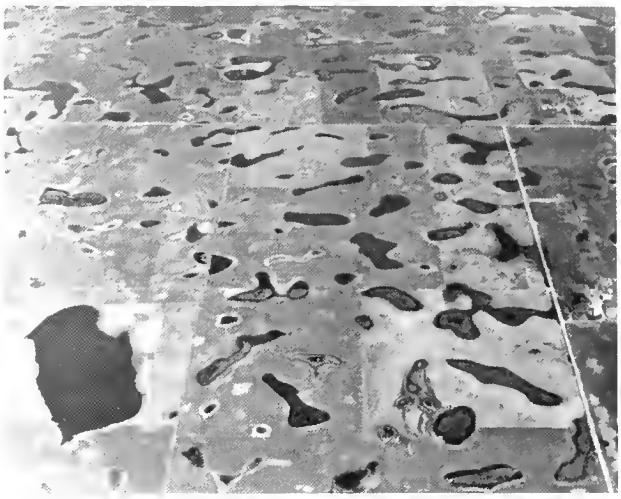

Fig. 2. Aerial view of a portion of the prairie pothole region in an area of intensive agriculture where seeded grasslands would provide nesting cover for dabbling ducks and habitat for other wildlife. (Photo courtesy of North Dakota Game and Fish Department)

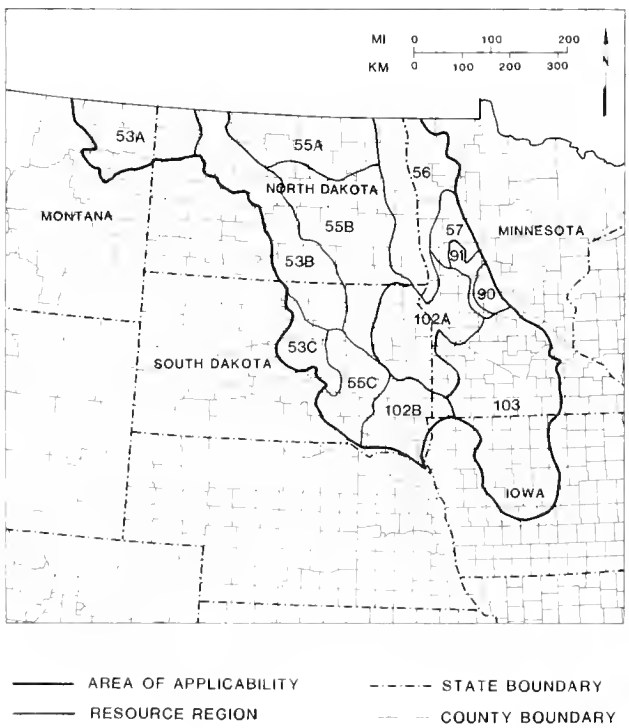

Fig. 1. Area of applicability and resource regions for grass planting guidelines described in this publication. (Map adapted from Land Resource Regions and Major Land Resource Areas of the United States, U.S. Department of Agriculture, Soil Conservation Service, Agricultural Handbook 296)

Fig. 3. A Waterfowl Production Area managed by the U.S. Fish and Wildlife Service. These small, scattered tracts of natural prairie wetlands provide habitat for feeding, courtship, and separation for dabbling duck pairs, as well as brood-rearing areas, but the adjacent uplands often require special management to provide good nesting cover.

Establishment and manipulation of upland plant communities to provide high-quality grassland cover are important management activities on lands administered by the U.S. Fish and Wildlife Service in the prairie pothole region. Skillful management of vegetation on upland habitats is an important factor in dabbling duck production because most species in the prairie pothole region nest in the uplands. Fortunately, it is possible to establish good grassland habitat on lands that have been previously tilled by planting introduced grasses and legumes or native grass. The best possible grassland stands should be maintained on wildlife management areas because these areas make up only a small proportion of the total habitat base for prairie wildlife. Intensive management to provide undisturbed habitats for wildlife is not probable on private land or public lands managed for other purposes.

Seeded grasslands are a crop of the soil just as is corn, barley, or wheat. Careful attention must be given to cultural practices, such as site preparation and seeding techniques, to ensure good stands of grass. If the technology developed by wildlife and agricultural researchers is to benefit wildlife production on managed habitat it must be made available in ways that will stimulate application by managers.

Seeded Grasslands as Wildlife Habitat

Recent studies have indicated the value of some types of seeded grasslands as nesting cover for prairie ducks in the glaciated prairie region (Duebbert 1969; Duebbert and Lokemoen 1976). Other researchers have emphasized the important relationship between cover quality and nesting activity of dabbling ducks. The number of nests per unit area and success of duck nests were related to visual obstruction measurements (height and density) of residual vegetation on the Woodworth Study Area in North Dakota (Kirsch et al. 1978).

The value of good grassland habitat to the welfare of other game species has been well established through published studies and practical experience of wildlife managers. One of the most extensive upland cover programs in North America was the U.S. Department of Agriculture's Soil Bank Program in the 1950's and 1960's. During the peak years of this program (1960-61), 28.7 million acres of cropland were retired from production of cereal grains and planted with introduced grasses and legumes as a cover crop. Haying or grazing was not permitted. In North Dakota, 2.7 million acres were in this program in 1960 and these undisturbed acres of seeded grasslands were excellent habitat for many species of wildlife. Pheasant *(Phasianus colchicus)* populations in South Dakota increased from 4-6 million birds to 8-11 million birds during the Soil Bank period (Dahlgren 1967). In the 1960's the Cropland Adjustment Program (CAP) provided similar benefits but on fewer acres (Jaenke 1966). In 1967, about 2 million acres were idled under this program in the United States of which 210,000 acres were in North Dakota. The value of habitat developed under these land retirement programs for ring-necked pheasants, sharp-tailed grouse *(Pedioecetes phasianellus)*, and greater prairie chickens *(Tympanuchus cupido)* was indicated by several studies (Dahlgren 1967; Gates et al. 1970; Kirsch et al. 1973).

The use of CAP fields for waterfowl nesting was affirmed in north-central South Dakota (Duebbert 1969; Duebbert and Lokemoen 1976). Studies at scattered locations elsewhere in the United States have shown that habitat created by planting introduced cool-season grasses and legumes and leaving them undisturbed provided a valuable cover type for nesting ducks and some other wildlife species. Duebbert and Lokemoen (1977) reported the utilization of upland fields of undisturbed tall, dense cover by nesting American bitterns *(Botaurus lentiginosus)*, marsh hawks *(Circus cyaneus)*, and short-eared owls *(Asio flammeus)*. Many species of passerine birds utilized stands of seeded grasslands dominated by introduced cool-season grasses and legumes. Several thousand acres of such cover—commonly referred to as dense nesting cover (DNC)—have been planted on lands managed by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana (Fig. 4). Principal species of vegetation used to establish DNC have included mixtures of tall wheatgrass *(Agropyron elongatum)*, intermediate wheatgrass *(A. intermedium)*, alfalfa *(Medicago sativa)*, and sweetclover *(Melilotus officianalis)*. Where wildlife use of stands of seeded cover in the prairie pothole region has been evaluated the data have usually indicated positive benefits from the presence of the cover.

Another program that resulted in the establishment of seeded grass-legume habitat was the USDA Water Bank Program that started in 1972 (Womach 1977). In the prairie pothole region within North Dakota, South Dakota, Minnesota, and Montana about 340,000 acres of upland cover were under 10-year Water Bank Program contracts in 1979. The Water Bank has proven to be a valuable program for protecting wetlands and enhancing adjacent upland habitats.

Criteria for Establishment of Seeded Grasslands

A proper place to establish seeded grasslands of either introduced cool-season grasses and legumes or

Fig. 4. Stand of seeded grassland composed of intermediate wheatgrass, alfalfa, and sweetclover showing a desirable mixture of residual and new vegetation in mid-June.

native grasses is on croplands or other lands where all native vegetation has been eliminated by previous farming. All remaining tracts of native prairie on wildlife management areas should be preserved and managed on a sound ecological basis. Cultivation of existing vegetation on previously farmed areas containing saline soils, alkaline claypan soils, or other soils with severe limitations for productivity should be carefully considered because of the extreme difficulty in reestablishing more desirable vegetation on the site. The use of introduced cool-season grasses and legumes or native grasses to establish seeded cover depends on management decisions and objectives. In any case, mixing introduced grasses and native grasses in a single stand is not recommended.

Most recent research in the prairie pothole region on the relationships between the number of duck nests per unit area and hatch rates in established upland cover has been accomplished in stands of introduced grasses and legumes (Duebbert 1969; Duebbert and Kantrud 1974; Duebbert and Lokemoen 1976). It is possible to produce stands of tall, warm-season native grasses with a similar cover form on some soils and sites in the eastern Dakotas and

Fig. 5. Stand of seeded grassland composed of intermediate wheatgrass, alfalfa, and sweetclover at Medicine Lake NWR, Montana, May 1980.

western Minnesota where annual precipitation is 20 inches or more. In these areas, big bluestem *(Andropogon gerardi),* indiangrass *(Sorghastrum nutans),* and switchgrass *(Panicum virgatum)* produce a vegetative form that is similar to cover established from introduced cool-season grasses and legumes. In areas of western North Dakota, eastern Montana, and the southern Canadian provinces, where annual precipitation may be 15 inches or less, it is more difficult to establish tall, dense grassland cover with native grasses. Introduced grasses such as intermediate wheatgrass or tall wheatgrass in a mixture with alfalfa produce stands of tall, dense vegetation in areas such as Medicine Lake National Wildlife Refuge at Medicine Lake, Montana, where the average annual precipitation is 12 inches (Fig. 5).

Field size is a factor to consider in establishing seeded cover for duck nesting habitat. No field is too small for grassland establishment, but greater duck nest densities and higher hatch rates have usually been found in relatively large fields (greater than 40 acres) that do not contain wetlands or other habitat divisions. To provide a complete dabbling duck production habitat the fields were surrounded by complexes of Class II, III and IV wetlands (Stewart and Kantrud 1971) adjacent to the field and within a radius of 2 to 3 miles. Adequate wetlands are required to provide habitat for breeding pairs and broods if managed nesting cover is to provide desirable benefits. An example of a good combination of prairie potholes and cover block for dabbling duck production is shown in Fig. 6.

In stands of seeded cover the diameter and strength of the plant stems are important because the vegetation will be resistant to flattening or lodging

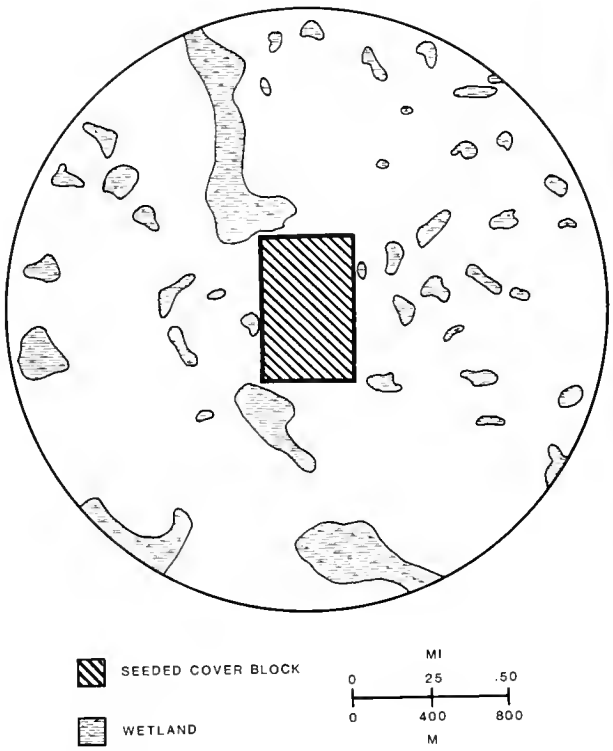

Fig. 6. Diagram of seeded grassland plot that provides dabbling duck nest sites in close proximity to surrounding wetland complex that is used by breeding pairs, nesting hens, and broods.

caused by winter snows. Grasses such as intermediate wheatgrass, tall wheatgrass, big bluestem, indiangrass, and switchgrass are particularly resistant to flattening. To provide the best cover for nesting ducks in the prairie pothole region, the residual cover in mid-April should be tall enough and dense enough to provide 100% effective screening to a height of 8 inches or more on a cover board or visual obstruction pole when viewed from a distance of 13 feet and a sighting height of 3 feet (Robel et al. 1970; Fig. 7).

Grasslands in the prairie pothole region that are managed to provide optimum wildlife habitat should not be subjected to annual grazing or haying to avoid detrimental effects on the essential component of residual vegetation. Seeded grasslands require rejuvenation treatments at intervals of several years and their management should be considered a never-ending activity if cover of optimum quality is to be maintained. Seeded grasslands generally produce more ducks and other game species within the first 2 to 8 years after establishment or rejuvenation. Rotation systems of cover management should be devised to capitalize on the relationship between

Fig. 7. Stand of seeded grassland dominated by intermediate wheatgrass showing abundance and form of residual vegetation in spring before new growth begins (1 May 1980). Pole marked in decimeters.

young, vigorous stands of vegetation and higher wildlife production.

Types of Seeded Grasslands in the Prairie Pothole Region

Seeded grasslands are relatively easy to establish compared with other habitat types, such as forests or wetlands, and prairie wildlife species begin using them rapidly. Thus, seeded grasslands can provide valuable wildlife habitat on public and private lands in the prairie pothole region. Several different kinds of seeded grasslands can be established and some of the major types are as follows.

Introduced Cool-season Grasses and Legumes

Good habitat for duck nesting and use by other prairie wildlife can be established by planting mixtures of introduced cool-season grasses and legumes on good-quality cultivated soils throughout the area of applicability (Fig. 8). Tall wheatgrass, intermediate wheatgrass, alfalfa, and sweetclover are well-suited for such habitats.

Intermediate wheatgrass is a vigorous, rhizomatous species that is native to central Europe, the Balkans, and Asia Minor (Rogler 1973). It is well adapted to planting on many soil phases and sites in the northern Great Plains where annual precipitation ranges from 8 to 20 inches. On farms and ranches it is used in mixtures with legumes for pasture and hayland. Several cultivars have been developed by agricultural researchers (Hanson 1972). The cultivar

Fig. 8. Mallard nest in a field of seeded nesting cover composed of intermediate wheatgrass and alfalfa.

"Oahe" developed in South Dakota is an excellent one for use in the prairie pothole region. Recommended varieties for the Canadian pothole region are "Chief" and "Greenleaf" (Anonymous 1979). Intermediate wheatgrass grows to a height of 4 to 5 feet on fertile soils with adequate precipitation. It is easy to establish and grows vigorously during the first 4 or 5 years but stands tend to deteriorate in height, density, and vigor after they have been established for 8 to 10 years.

Tall wheatgrass is a tall, coarse bunchgrass that is native to saline meadows and seashores of southeastern Europe and Asia Minor (Rogler 1973). Tall wheatgrass is especially recommended for planting on poorly drained and very poorly drained soils. It also produces excellent stands on well-drained upland soils in areas with annual precipitation as low as 8 inches. "Alkar" and "Platte" are two cultivars that are well adapted to the prairie pothole region. The cultivar "Orbit" is recommended for southern Manitoba, Saskatchewan, and Alberta (Anonymous 1979).

Varieties of alfalfa that have desirable vegetative characteristics include "Ranger," "Ladak," and "Grimm." Good stands of cover composed of intermediate wheatgrass, tall wheatgrass, and alfalfa have been established under a remarkably wide variety of soil, moisture, and climatic conditions in the prairie pothole region. For example, stands have been established at different sites in an area bounded by Fergus Falls, Minnesota; Great Falls, Montana; southern South Dakota, and northern North Dakota.

The grass-legume mixture used as seeded cover also has excellent soil-building properties when organic matter and plant nutrients are added (Derschied et al. 1971). When used in rotational cover management systems with periodic tillage, the soil is improved with each treatment. Many soils on wildlife management areas have been degraded through previous abuse and would be benefited by proper care including grass-legume cover.

Tall, Warm-season Native Grasses

Whitman (1963) recognized three potential grassland types within North Dakota. Generally, the descriptions are applicable for the three types within the prairie pothole region. The True Prairie with big bluestem, little bluestem *(Andropogon scoparius)*, indiangrass, porcupine grass *(Stipa spartea)*, prairie dropseed *(Sporobolus heterolepis)*, and prairie cordgrass *(Spartina pectinata)* as the dominant species composition occupies virtually all of the Red River Valley. A transitional type of grassland dominates the central part of the State on the Drift Plain. The potential vegetation is needleandthread *(Stipa comata)*, green needlegrass *(S. viridula)*, western wheatgrass *(Agropyron smithii)*, slender wheatgrass *(A. trachycaulum)*, little bluestem, blue grama *(Bouteloua gracilis)*, prairie junegrass *(Koeleria cristata)*, and bluegrass *(Poa pratensis)*.

A comparatively xeric mixed prairie is found on the Missouri Plateau with needleandthread, blue grama, thread leaved sedge *(Carex filifolia)*, and western wheatgrass as the major species, whereas plains muhly *(Muhlenbergia cuspidata)*, and little bluestem are locally abundant on eroded slopes. Prairie sandreed *(Calamovilfa longifolia)* is important on sandy and sand range sites throughout North Dakota.

Adapted varieties of tall warm-season native grasses can be used to establish seeded grasslands on cultivated soils in eastern parts of the prairie pothole region. Seeded as a mixture, big bluestem, indiangrass, and switchgrass produce a stand of vegetation with a tall, dense form (Fig. 9). Big bluestem, indiangrass, and switchgrass are characteristic of mesic sites in the tallgrass prairie region. These species are composed of many ecotypes and have ranges of adaptation to soils and climate. They occur on subirrigated lowlands, on nearly level

Fig. 9. Stand of tall, warm-season native grasses composed of big bluestem, switchgrass, and indiangrass produced by seed derived from local ecotypes and planted at Jamestown, North Dakota, on 26 May 1978. This photo shows the desired form and structure of residual vegetation before the addition of new growth on 25 May 1980. Pole marked in decimeters.

to gently undulating glacial till plains, overflow sites, level swales and depressions, residual and glacial uplands, and bottomlands along rivers and streams. These tall native grasses also occur on nearly level to rolling glacial till plains, lake plains, and on high stream terraces in the southeastern portions of the prairie pothole region.

Big bluestem is a tall warm-season perennial native grass with long root systems and short underground rhizomes. It sometimes reaches a height of more than 6 feet at maturity. "Pawnee" is a tall, leafy, late-maturing big bluestem, and has potential for use as wildlife habitat in the tallgrass prairie of southeastern North Dakota, eastern South Dakota, west-central Minnesota, and eastern Nebraska and Iowa. Pawnee may sustain some winter injury during the year of establishment in northern latitudes, unless covered with snow. "Champ" was developed from an interbreeding population of big bluestem and sand bluestem, and it is not recommended for use in the northern part of the prairie pothole region. Three additional experimental strains of big bluestem are currently being field tested for use in the northern Great Plains: PM-SD-27 developed by the USDA-SCS, Plant Materials Center (PMC), Bismarck, North Dakota; NDG-4 developed by USDA Science and Education Administration-Agricultural Research (SEA-AR), Mandan, North Dakota; and SD-43 developed by South Dakota State University, Agricultural Experiment Station, Brookings. Three cultivars have been released for use in the southern and central Great Plains: "Kaw," developed by the Kansas Agricultural Experiment Station, has a range of adaptation that extends into the southern prairie pothole region. Pawnee and Champ were released by SEA-AR (formerly the Agricultural Research Service) in cooperation with the Nebraska Agricultural Experiment Station.

Indiangrass is a tall warm-season grass with short rhizomes adapted to the tallgrass prairie region of Iowa, Minnesota, and the eastern Dakotas and to subirrigated and overflow range sites in the mixed-grass prairie zones of North Dakota. Several varieties have been released, two of which were developed by the University of Nebraska Agricultural Experiment Station and SEA-AR. "Holt" was developed by mass selection from field collections in the Elkhorn Valley of Holt County in northeastern Nebraska. It was released as a moderately early-maturing variety with fine leaves and stems. "Oto" was developed from collections from natural grasslands of Nebraska and Kansas. It is a late-maturing, robust, erect variety. PM-ND-444 is a composite from three field collections in south central North Dakota and north-central South Dakota. Although this variety has not been officially released, seed is available from the SCS Bismarck PMC for testing in field plantings. "Nebraska 54" is a tall, leafy, late-maturing selection adapted to eastern and southern Nebraska and adjacent States. The origin of Nebraska 54 was certified by the Nebraska Crop Improvement Association.

Switchgrass is a tall native perennial, warm-season, strongly rhizomatous grass adapted to moist, deep, fertile soils. Good seed characteristics and strong seedling vigor make this an excellent species for use in establishing seeded grasslands in areas of adaptation. Tolerance to pre-emergence herbicides such as atrazine and simazine, and seed characteristics, contribute to relative ease of establishment of switchgrass compared with other warm-season native grasses. "Nebraska 28" is characterized by fine stems and bluish-green leaves, and is well adapted to a wide range of soils throughout the prairie pothole region (Fig. 10). "Cave-in-Rock" is a tall, coarse, lowland type that originated from a seed collection near Cave-in-Rock, Illinois, and was released by the SCS Plant Materials Center, Elsberry, Missouri. It is adapted to Iowa and possibly southern Minnesota. "Pathfinder" is a vigorous, leafy, late-maturing, disease-resistant variety released by the Nebraska Agricultural Experiment Station in cooperation with SEA-AR. Pathfinder is adapted to eastern Nebraska, Iowa, central Minnesota, and eastern South Dakota. "Summer" originated from a native collection near Nebraska City, Otoe County, Nebraska. It is a tall, upright,

Fig. 10. Stand of Nebraska 28 switchgrass established at Jamestown, North Dakota, from a planting on 2 June 1971. Burned in 1975 and 1978 (25 May 1980).

leafy type, released by the South Dakota Agricultural Experiment Station. Summer is adapted to eastern South Dakota, southeastern North Dakota, and west-central Minnesota. PM-SD-149 is a field collection from an upland site near Forestburg, South Dakota. It was selected by the USDA-SCS on the basis of superior forage and seed production. PM-SD-149 has not been officially released, but seed is available for field testing. NDG-965-98 is a northern, early-maturing, upland type collected by SEA-AR near Mandan, North Dakota. It performs well in North Dakota, but it is not adapted to the higher temperatures, humidity, and shorter day length of the south-central portion of the prairie pothole region. Some seed is commercially available.

In general, tall, warm-season native grasses are more difficult to establish than introduced species. However, after becoming established the native grasses remain in a vigorous condition longer than introduced species and can be periodically rejuvenated by prescribed burning.

The type of seedbed preparation is very important to the successful establishment of native grasses. Coarse-textured (sandy) soils should be planted to an annual grain crop for 1 year and the tall, warm-season grasses seeded directly into clean standing stubble the following spring without further tillage or seedbed preparation. The prepared seedbed method may be used for spring seedings on fine (clay-silt) to moderately textured (loam) soils.

Several wetland managers of the U.S. Fish and Wildlife Service in western Minnesota, eastern South Dakota, and eastern Nebraska have established excellent stands of high-quality, warm-season native grasses by using primarily big bluestem, indiangrass, and switchgrass. In studies conducted in the Waubay Wetland Management District (WMD) of South Dakota during 1970-72 and the Devils Lake WMD of North Dakota, plantings of mixed cool-season and warm-season native grasses provided satisfactory nesting cover for dabbling ducks (Klett et al., unpublished data). George et al. (1979) reported that seeded stands of tall, warm-season native grasses provided suitable nest cover for ring-necked pheasants in Iowa. High densities of dabbling duck nests, primarily blue-winged teal *(Anas discors),* have been recorded in planted native grasses at Lake Andes National Wildlife Refuge at Lake Andes, South Dakota (Gary Zahm, personal communication).

Mixed-grass Prairie Native Grasses

The purpose of this section is to present guidelines for selecting certain species and varieties which should be used in converting cropland to seeded tallgrass and mixed-prairie grasslands in the transitional area (Major Land Resource Areas 53A, 53B, 55A, and 55B) where climate and soils impose increasingly greater limitations to grass establishment from east to west. Native forbs are an important part of natural grassland plant communities but they are not discussed because of the scarcity of commercial seed sources and high prices. Using high-quality prairie hay as a mulch or harvest and planting seed of adapted local native plants may add diversity to the stand. However, if the hay-mulch method is used, extreme caution should be used to prevent introduction of undesirable seeds.

Selected species of native grass found in the mixed-grass prairie region and varieties suitable for use in establishing seeded grasslands are described below.

Western wheatgrass is a perennial, sod-forming, native cool-season grass with drought resistance, winter hardiness, and adaptability to a wide range of soil and climatic conditions. "Rosanna" is the direct increase of a field collection from a native meadow northwest of Forsyth, Montana. Selected on the basis of seedling vigor, strong rhizomes, forage, and seed production, it was released by SCS. "Mandan 456" originated from a field collection made near Mandan, North Dakota. It was selected by SEA-AR, Mandan, North Dakota, for density, leafiness, and rust resistance but was not officially released. "Barton" originated from a native grassland near Heizer, Kansas. It is a strongly rhizomatous, leafy ecotype with superior forage production and disease resistance that was released cooperatively by Kansas Agricultural Experiment Station, the SCS, and SEA-AR.

Slender wheatgrass is a native, perennial, cool-season bunchgrass with good seedling vigor and

tolerance to saline and alkaline soil conditions. It is relatively short-lived and less drought-resistant than western wheatgrass. "Primar" is an early-maturing, leafy, disease-resistant cultivar.

Thickspike wheatgrass *(Agropyron dasystachyum)* is a strongly rhizomatous, cool-season perennial native grass widely distributed throughout the northern Great Plains. "Critana," the direct increase of a field collection near Havre, Montana, was released by the SCS and Montana Agricultural Experiment Station.

Green needlegrass is a cool-season, drought-tolerant, native perennial bunchgrass adapted to a wide range of soil textures in the northern Great Plains. It provides good cover for dabbling duck nesting and is relatively easy to establish. Seed is available from commercially harvested native grasslands and "Lodorm" is a released variety. Lodorm was developed by recurrent selection for low seed dormancy from a collection made in a native grassland north of Bismarck, North Dakota. It was released cooperatively by Montana, North Dakota, and South Dakota Agricultural Experiment Stations and SEA-AR.

Needleandthread is a cool-season native bunchgrass with long-barbed awns. It is widely distributed on silty, sandy, or gravelly sites. No suitable varieties are available for planting in the prairie pothole region.

Sideoats grama *(Bouteloua curtipendula)* is a weakly rhizomatous, native, warm-season perennial grass. It is a component in many upland grassland communities where it is most commonly found on poorly developed shallow soils, steep slopes, ridgetops, and sandhill areas. Seed of several released varieties is commercially available: "Pierre" is a composite of seed collected west of Pierre, South Dakota. Selected for vigor and leafiness, it was tested and informally released by SCS. "Killdeer" is an increase of seed collected from native grasslands in Bowman and Dunn counties, North Dakota, and was informally released by the USDA-SCS. Seed is commercially available. "Butte" was developed from native seed collection in Holt and Platte counties, Nebraska. It was released by Nebraska Agricultural Experiment Station, SCS, and SEA-AR.

Blue grama is a winter hardy, low-growing, native, perennial warm-season grass with a basal type of growth that forms a densely tufted sod. Plant height at maturity ranges from 6 to 12 inches. It is adapted to a wide range of soil phases, but is most abundant on fine-textured rolling uplands. Because blue grama resists drought, it occupies drier sites throughout its range of adaptation. "Lovington," released by the New Mexico Agricultural Experiment Station and the SCS, is not adapted to the northern prairie pothole region. A wide range of ecotypes occur from north to south in the Great Plains. There are no varieties of blue grama recommended for use in the prairie pothole region. Seed harvested from natural grassland in the central and northern plains should be used.

Little bluestem is a native, perennial, warm-season bunchgrass with excellent drought tolerance and is widely distributed throughout the prairie pothole region. Plant height ranges from 24 to 48 inches. "Aldous" is a late-maturing variety from the Flint Hills area of Kansas that was released by the Kansas Agricultural Experiment Station and the SCS. It is moderately adapted to the southern portion of the prairie pothole region. "Blaze," developed from domestic collections from native prairie in Nebraska and Kansas, was selected for late maturity, leafiness, and seed production. Blaze was released by Nebraska Agricultural Experiment Station and SEA-AR. The primary area of adaptation is central and eastern Nebraska. "Camper" was released by Nebraska Agricultural Experiment Station and SEA-AR. The parent lines trace to domestic collections from native prairie sources in Nebraska and Kansas.

Prairie sandreed is a native, perennial, warm-season, strongly rhizomatous, drought-tolerant grass that is adapted to sandy soils. "Goshen" is the direct increase of a field collection made near Torrington, Wyoming. Released cooperatively by the SCS Plant Materials Center in Bridger, Montana, and the Montana and Wyoming Agricultural Experiment Stations.

Other Grasses

Reed canarygrass *(Phalaris arundinacea)* is a tall, coarse, sod-forming, cool-season perennial grass with strong rhizomes. It is adapted to fertile low and wet areas, and to muck and peak lands. It is relatively drought tolerant when grown on upland soils. However, unless heavily fertilized it becomes relatively unproductive of vegetation within a few years. Two varieties are suitable for use in the prairie pothole region: "Frontier," released by the Canada Department of Agriculture Research Station, Ottawa, and "Ioreed," released cooperatively by Iowa Agricultural Experiment Station and SCS from selected plant introduction and a domestic collection.

Factors that Affect Establishment of Seeded Grassland

Only a small proportion—less than 5%—of the total land base in the prairie pothole region is devoted primarily to wildlife habitat management. Therefore,

grassland habitats should be maintained on these areas that are the best possible under prevailing soil and climatic conditions. Waterfowl and other species of prairie wildlife are capable of producing large numbers of young in optimal environments. Proper planning and adequate attention to essential details will help establish good stands of seeded grasslands. Longevity will be extended and future management will be less of a problem if a good stand is attained initially. In this section, certain factors are discussed that are important in establishment of seeded grasslands.

Site Adaptability

Success in the establishment and maintenance of seeded grasslands is closely correlated with soil type, slope, moisture regimes, and other site factors. In the Dakotas, the best stands of introduced cool-season grasses and legumes have been established on Class II or III soils (USDA-SCS 1978*b*) on level to gently undulating terrain with slopes of 0 to 10%. Good stands have been attained in some areas on Class IV soils with steeper slopes. Sites purchased for some wildlife management areas often do not meet these criteria and special attention should be directed at establishment methods. Introduced cool-season grasses and legumes will probably eventually require periodic rejuvenation by tillage. Thus, this type of cover is best suited to areas where soil erosion from cultivation is slight. Class VI lands should normally be seeded to native grasses.

Soils on which tall, warm-season native grasses grow best are moderately deep to deep, well-drained, and medium to moderately fine textured. Permeability of these favorable soils is moderate and available water capacity is usually high or very high.

Additional planning considerations for restoring cropland to seeded grassland communities within the limits of current technology and available seed sources are presented in the section entitled *Seed Sources*.

Site Preparation

The type of site preparation to be used is associated with soil texture and slope. The tilled seedbed method is preferred for most seedings and may be used on fine (clay-silt) to moderately textured soils. Coarse textured (sandy) soils should be planted to an annual grain crop in 1 year and the grass seeded directly into clean, standing stubble.

Control measures to reduce or eliminate undesirable vegetation should be planned during site preparation and well in advance of the grass seeding. Fields that have not been tilled recently and contain quackgrass *(Agropyron repens),* smooth bromegrass *(Bromus inermis),* Canada thistle *(Cirsium arvense),* leafy spurge *(Euphorbia podperae),* or perennial weeds may require one or more years of intensive cultivation, herbicide treatment, or both. If only tillage is used, numerous tillage operations may be required to suppress competing vegetation. A final tillage just before freeze-up in the fall has been effective in killing rhizomes of undesirable perennial grasses and weeds. Several tillage methods have been designed to keep plant residue on the soil surface and thus reduce runoff, evaporation, and erosion. Selective herbicides are available and should be carefully evaluated as alternatives to tillage.

It is essential to adequately control competing vegetation before attempting to establish seeded grasslands. Inadequate weed suppression is the cause of grass seeding failures more than any other single factor. A field at the Northern Prairie Wildlife Research Center near Jamestown, North Dakota, provides an example of what can be accomplished with good site preparation and proper seeding techniques. The site had been previously cultivated and was vegetated for 15 years primarily with quackgrass. Procedures followed to establish an excellent stand of tall, warm-season native grasses were (1) quackgrass was killed by intensive summer fallowing (six to eight cultivations were made annually for 2 years and a final cultivation just before freeze-up); (2) the seedbed was packed very firmly; and (3) seeding was done on 30 May with a special grass drill so that the seeds were placed in the compacted soil at the proper depth. Adequate rainfall during June and July provided excellent conditions for germination and growth of the grasses. Big bluestem, indiangrass, and switchgrass attained heights of 4 to 5 feet and produced seed during the year of establishment.

Bryan and McMurphy (1968) reported excellent seedling vigor of native grass cultivars on a weed-free seedbed. Cornelius (1946) stated that reseeding was superior to natural secondary succession in revegetating abandoned cropland. Experience of land managers in western Minnesota and at some sites in the eastern Dakotas has shown that good stands of tall, warm-season, native grasses can be attained in those areas.

Seedbed Preparation

Seedbed condition is a very important factor in successfully establishing perennial grasses and legumes. Clean-cultivated seedbeds may be prepared with conventional tillage equipment. Another impor-

tant factor in successful establishment of grasses is the degree of compaction of the seedbed. After tillage, the soil should be packed firmly with a spike-tooth harrow or corrugated roller. The soil has been compacted to the desired firmness when a man's footprint in it is less than 1/2 inch deep. Fine-textured soils (or "clayey soils") should not be tilled when they are wet because this results in a cloddy or puddled condition.

The protective-crop method of seedbed preparation can be applied on medium- and coarse-textured soils or steep slopes where wind and water erosion are problems. A protective crop includes a planting of an annual grain crop that is harvested to leave a stand of stubble. The protective crop can be planted after site preparation that includes clean-tilled summer fallow. Delay planting of the protective crop in spring until one or more crops of annual weeds have germinated during year 1 and have been killed by shallow tillage. One option is to prepare a firm seedbed and plant close-drilled sudangrass *(Sorghum sudanense)* between 15 June and 1 July. Spring-seeded annual crops such as oats *(Avena sativa)*, barley *(Hordeum vulgare)*, flax *(Linum usitatissimum)*, grain sorghum *(Sorghum bicolor)*, or millet *(Panicum miliaceum)* provide satisfactory cover crops. Mow and remove the vegetation leaving a 12- to 15-inch stubble (USDA-SCS 1978*a*).

Drill perennial grasses directly into the standing stubble without disturbing the soil. Planting into rye *(Secale cereale)* stubble is not recommended because this crop is very competitive and produces volunteer plants for 2 to 3 years. An application of the herbicide glyphosate before planting or prior to emergence of grasses may be used to control volunteer weed growth. Refer to Extension Service recommendations and follow the manufacturer's instructions on the label. The standing stubble method provides an excellent seedbed for fall-dormant or spring plantings using either cool- or warm-season grasses. Warm-season grasses should not be planted in fall. The microclimate created by the standing stubble reduces evaporation and crusting or compaction of soils. However, in northern latitudes, soil temperatures in April and most of May are lowered, partially offsetting the advantages of seeding into stubble to establish warm-season grasses.

The seeding of flax, some small grains, or other crops as companion crops is not recommended with native grasses. The use of companion crops with introduced grasses and legumes is optional. If companion crops are used, flax is the least competitive and other small grain companion crops, such as oats and barley, should be seeded at 1/3 to 1/2 normal rates and mowed at a height of about 15 inches when the grain is beginning to form seed. Use of wheat *(Triticum aestivum)* or rye as companion crops is not recommended. Genest and Steppler (1973) studied the effects of oats, barley, and wheat as companion crops on grass establishment and found that best results were obtained by not using any companion crop.

Planting Equipment and Methods

The primary requirements for planting perennial grasses and legumes include (1) uniform distribution of seed at the proper rate per acre, (2) placing the seed at the proper depth, and (3) firming the soil around the seed. Drills designed to plant a wide range of native and introduced grass and legume seeds are commercially available. They are equipped with special seed boxes, agitators, depth bands, and packer wheels to meet the primary requirements of planting perennial grasses.

Ground vehicle and aerial broadcast seeding of grass seeds are not recommended. However, we recognize that it is possible to establish good stands of seeded grasslands by broadcasting under optimum moisture conditions. Wilson et al. (1970) compared drill and broadcast methods for crested wheatgrass *(Agropyron cristatum)* and found that drilling gave much better results because of more constant moisture and temperature relations for seedlings. Bement et al. (1965) obtained the best results in grass establishment from drilling on fallowed soil. If it is necessary to use a broadcast method, then double the seeding rate and pack the soil surface firmly with a corrugated roller or spike-tooth harrow after seeding.

Proper depth of planting is essential to successful stand establishment of seeded grasses and legumes. The kind and size of seed, soil texture, and moisture conditions are the principal factors that influence seeding depth. Seeds should be planted at a depth of 1/2 to 3/4 inch in medium- to fine-textured soils and approximately 1/2 to 1 inch—and never more than 1-1/2 inches—in coarse-textured, sandy soils.

Rates and Dates of Seeding

Grasses and legumes should be seeded when soil moisture and temperature conditions are optimum for germination of the various species. Cool-season grasses and legumes will germinate and emerge at lower temperatures than warm-season native grasses. Three alternative times are acceptable for seeding cool-season introduced grass: (1) early spring before 1 May; (2) late summer to early fall, 10 August to 10 September if soil moisture is adequate for germination; or (3) late fall dormant seedings after 20 October. Late fall seedings should be so late that germination cannot occur and seeds remain dormant

Table 1. *Optimum seeding dates for introduced and native cool-season grasses and legumes (adapted from USDA-SCS 1978b).*

Major land resource area[a]	Seeding dates		
	Spring[b]	Late summer[c]	Late fall[d]
53A	15-30 April	1-15 Aug.	After 25 Oct.
53B	1-15 April	1-15 Aug.	After 25 Oct.
53C	15-30 March	15-30 Aug.	After 1 Nov.
55A	15-30 April	1-15 Aug.	After 20 Oct.
55B	1-15 April	1-15 Aug.	After 25 Oct.
55C	15-30 March	15-30 Aug.	After 1 Nov.
56	1-15 April	15-30 Aug.	After 1 Nov.
57	15-30 April	1-15 Aug.	After 25 Oct.
90	1-15 April	1-15 Aug.	After 25 Oct.
91	15-30 April	1-15 Aug.	After 25 Oct.
102A	1-15 April	1-15 Aug.	After 1 Nov.
102B	15-30 March	15-30 Aug.	After 1 Nov.
103	15-30 March	15-30 Aug.	After 1 Nov.

[a] See Fig. 1.
[b] Plant as early as possible. Planting time can be extended at least 30 days beyond optimum if weather or soil conditions are wet.
[c] Plant only when soil moisture is adequate. Plant early enough to allow at least 40 days for seedlings to develop before they go dormant in the fall.
[d] Dormant seedings are made for spring germination; therefore, they must be planted late enough so there is no chance of fall germination.

over winter. Preferred seeding dates are before 15 May for cool-season introduced or native grasses and 1 to 15 June for warm-season native grasses. All factors considered, spring plantings by drilling on seedbeds adequately prepared by tillage, preferably summer-fallowed, are most likely to result in the best stands of seeded grassland. Optimum seeding dates for introduced cool-season grasses and legumes, native cool-season grasses, and native warm-season grasses are shown in Tables 1 and 2. Seeding rates of 20 to 40 pure live seeds (PLS) per square foot are needed to establish adequate stands of perennial grasses in the glaciated prairie pothole region.

Our discussion of the PLS concept is adapted from Kinch (1964). The seeding rate should be adjusted for each species, variety, or seed lot in the mixture. The optimum seeding rate is an interaction of the seed, field condition, and climate. The inherent genetic factors, expressed as percentage germination and seedling vigor, interact with environmental factors—soil, site, moisture, and competition—to determine stand establishment. Seed germination is influenced by stage of maturity at harvest time, age, and storage conditions. Seed origin, size, and mechanical damage have also been correlated with seedling vigor. Moisture and weed competition are two important

Table 2. *Optimum seeding dates for native warm-season grasses (adapted from USDA-SCS 1978b).*

Major Land Resources Area (MLRA)[a]	Seeding dates[b]
53A	Not recommended
53B	1-15 June
53C	1-15 June
55A	1-15 June
55B	1-15 June
55C	1-15 June
56	1-15 June
57	1-15 June
90	1-15 June
91	1-15 June
102A	1-15 June
102B	15-30 May
103	15-30 May

[a] See Fig. 1.
[b] Optimum seeding time depends on temperature and soil moisture. In northern MLRA's successful seedings may be made at least 2 weeks before or after the indicated optimum depending on local conditions. Not recommended for fall seeding.

Table 3. *Number of pure live seeds per linear foot for 6-, 8-, or 12-inch row spacing based on optimum full seeding rates in PLS pounds per acre.*

Plants	Optimum full seeding rates PLS pounds/acre	Seeds per linear foot Row spacing (inches) 6	8	12	Recommended[a] Purity	Germination
Native grasses						
Big bluestem	10.6	20	30	40	70	60
Indiangrass	10.0	20	30	40	75	60
Switchgrass	4.5	20	30	40	95	80
Western wheatgrass	11.9	15	20	30	85	80
Slender wheatgrass	5.5	10	15	20	95	85
Thickspike wheatgrass	8.5	15	20	30	95	90
Streambank wheatgrass	8.4	15	20	30	95	90
Green needlegrass	9.6	20	30	40	90	70
Needleandthread	11.4	15	20	30	80	70
Little bluestem	6.7	20	30	40	70	60
Sand bluestem	15.4	20	30	40	70	60
Prairie sandreed	6.4	20	30	40	80	70
Sideoats grama	9.1	20	30	40	75	60
Blue grama	2.1	20	30	40	50	60
Reed canarygrass	3.2	20	30	40	95	70
Introduced grasses						
Tall wheatgrass	11.0	10	15	20	95	85
Intermediate wheatgrass	10.0	10	15	20	95	85
Smooth bromegrass	6.4	10	15	20	90	85
Legumes						
Alfalfa	4.4	10	15	20	95	90
Sweetclover	3.4	10	15	20	95	90

[a] Percent purity and germination are shown as minimum standards for good quality seed.

environmental factors limiting the successful establishment of seeded grasslands. A seeding rate of 40 PLS per square foot is recommended for seeding native grasses in the tallgrass prairie portion of Iowa, Minnesota, eastern South Dakota, and North Dakota including Major Land Resource Areas 56, 102A, 102B, and 103 (Fig. 1), and other sites further west where moisture is adequate. The higher (i.e., +40 PLS) seeding rates are designed to allow more effective competition with annual weeds and to accelerate the rate of establishment.

A seeding rate of 30 PLS per square foot is considered optimum for the mixed-grass prairie transition zone (Major Land Resource Areas 53B, 53C, 55A, and 55B) and 20 PLS per square foot for the drier mixed-grass prairie of central and western portions of South Dakota and North Dakota (Major Land Resource Areas 53A and 54).

A seeding rate of 20 PLS per square foot is recommended for seeding the mixture of tall wheatgrass, intermediate wheatgrass, alfalfa, and sweetclover, in all major Land Resource Areas in the area of applicability (Fig. 1).

Pure live seed is a single expression derived by multiplying the purity times the germination. The label on each bag or lot of seed provides information about the kind and quality of the seed. Two important items are the pure seed (purity) and germination percentage.

Example:

A big bluestem seed tag shows 82.45% pure seed and 73% germination. To determine the PLS, multiply the pure seed percentage (82.45%) by the germination percentage (73%) and divide by 100.

$$82.45 \times 73.00/100 = 60.18\% \text{ PLS}$$

The PLS shows that 60% of the material in the bag is viable big bluestem seed and that 40% is inert matter and other seeds.

The PLS values can be used to compare seed lots to determine which is the higher quality. Minimum PLS standards can be established for different kinds of seed to ensure specified quality of seed (Table 3). All seed should have a current germination and purity test. Pure live seed rates may be converted to bulk

Table 4. *Conversion factors to determine pounds of bulk seed needed to obtain 1 pound of pure live seed (adapted from Conservation Job Sheet ND-20, USDA-SCS 1980).*

Percent purity	Percent germination										
	100	95	90	85	80	75	70	65	60	55	50
100	1.0	1.05	1.1	1.2	1.25	1.35	1.4	1.55	1.65	1.8	2.0
95	1.05	1.1	1.2	1.25	1.3	1.4	1.5	1.65	1.75	1.9	2.1
90	1.1	1.2	1.25	1.3	1.4	1.5	1.6	1.7	1.85	2.0	2.2
85	1.2	1.25	1.3	1.4	1.45	1.55	1.7	1.8	1.95	2.15	2.35
80	1.25	1.3	1.4	1.5	1.55	1.65	1.8	1.9	2.1	2.25	2.5
75	1.35	1.4	1.5	1.55	1.65	1.8	1.9	2.05	2.2	2.45	2.65
70	1.4	1.5	1.6	1.7	1.8	1.9	2.05	2.2	2.4	2.6	2.85
65	1.55	1.65	1.7	1.8	1.9	2.05	2.2	2.4	2.55	2.8	3.1
60	1.65	1.75	1.85	1.95	2.1	2.2	2.4	2.55	2.8	3.05	3.35
55	1.8	1.9	2.0	2.15	2.25	2.45	2.6	2.8	3.05	3.35	3.65
50	2.0	2.1	2.2	2.35	2.5	2.65	2.85	3.1	3.35	3.65	4.0

pound seeding rates by multiplying by the factor indicated for purity and germination of the seed lot (Table 4).

Two methods can be used to select drill calibration and assist with establishing seeding rates.

Seeds per foot method.—Refer to Table 3 to determine the number of seeds per linear foot for various row spacings on PLS basis for recommended seeding rates. The number of seeds have to be increased to adjust for germination of seed. Select the conversion factor for the germination percentage of your seed lot from the full seeding rate column. Multiply the number of seeds per foot of row (Table 3) by this conversion factor. Run the drill over a hard ground surface, concrete floor, or tarpaulin; measure a foot of row, and count the number of grass seeds. Adjust the drill until it is delivering the approximate number of seeds per foot as calculated above. When mixtures are being seeded, use the percentage of each species in the mixture to calculate the number of seeds per foot of row. Seeds per foot for other row spacings not listed on the chart can be interpolated (multiply the figure in the 6-inch column by the ratio spacing used [inches] divided by 6 inches).

Weight method.—Jack up one end of the drill and measure the circumference of the drive wheel (Table 5). From Table 5 determine the number of revolutions of the drive wheel (R) using row spacing and wheel circumference (C) for the drill.

Put some seed into the box and turn the drive wheel until all seed spouts are feeding well. Place a container under the correct number of seed spouts (from Table 5) and turn the drive wheel the number of revolutions previously determined. Weigh the sample in grams, multiply this weight by 0.5, and the result is pounds per acre at that setting. Make adjustments in the drill setting and continue trials until the desired seeding rate is obtained. Weights used in this method are based on seeding rates of the bulk weight of commercial seed.

Seed mixtures to provide a stand of cover with introduced cool-season grasses and legumes include about 8 pounds of tall or intermediate wheatgrass, or both, and 1 pound of alfalfa per acre. Results have been variable from the inclusion (i.e., with, or in place of, alfalfa) of sweetclover in the mixture. Experience indicated that rates of 2 or 3 pounds per acre created too dense a stand the second year and suppressed grasses. If sweetclover is used, not more than 0.5 pound per acre is recommended. Canopy cover in an established stand of introduced cool-season grasses and legumes should be composed of about 75% grasses and 25% legumes. On many sites, poor stands result from having too much alfalfa in the stand. Stands should contain a large amount of standing and partially lodged dead vegetation from previous years. Green vegetation contributes increasingly to the overall cover during May and June due to the cool-season growth characteristics.

Table 5. *Determination of seeding rate using the weight method.*

Row spacing (inches)	No. of seed spouts to use	Revolutions of drive wheel
6	4	96 C=R[a]
7	4	82 C=R
8	3	96 C=R
10	3	77 C=R
12	2	96 C=R
24	1	96 C=R
30	1	77 C=R
36	1	64 C=R
42	1	55 C=R
48	1	48 C=R

[a] C=wheel circumference; R=revolutions of drive wheel

Use of Soil Information

The following planning considerations are designed to facilitate the establishment of seeded grassland communities on cultivated soils within the limits of current technology and available seed sources. Soil surveys include valuable information and interpretations that can be used to achieve the proper management of selected lands for wildlife habitat.

Soil surveys are an inventory of the soil resources of an area. Maps are available showing the distribution of soil phases in relation to other physical and cultural features.

Procedures to follow in determining seeding mixtures and rates are explained in the following three steps:

• Step 1. Use a soil survey to determine soil mapping unit, land capability class, and range site.

Soil mapping units represent the kinds of soil in a survey area. Each map unit is given a symbol or number that identifies the soil on the detailed soil maps. The soil description includes general facts about the soil and a brief description of the soil profile.

An evaluation of the soil characteristics—texture, depth, permeability, water-holding capacity, soil reaction (pH), salinity, and topographic features (length and degree of slope)—will assist in determining the type of vegetation needed to meet the desired habitat management objectives.

Capability classes are generalized groupings of soils rated I to VIII which indicate progression of greater limitations and narrower choices of the soils for different uses. These classes can be used in determining suitability of sites for conversion from cropland to grassland by using introduced or native species. Classes I to VI include most of the agricultural lands within the prairie pothole region.

Soils differ in their capacity to produce natural vegetation. Range sites are used for purposes of classifying range resources. A range site is a distinctive kind of rangeland that differs from other kinds in its ability to produce a characteristic natural plant community. A range site is the product of all the environmental factors responsible for its development, especially the soils. Therefore, certain specific soils are generally associated with a given range site (USDA-SCS 1976).

Range condition refers to the present state of a range site relative to the potential plant community for that site. The site is in *excellent condition* if 76 to 100%, by weight, of the stand consists of the plants of the potential plant community; *good condition* if it is 51 to 75%; *fair* if it is 26 to 50%; and *poor* if it is 0 to 25%. These terms also apply to the seeding and establishment of native plant communities.

• Step 2. Consult the SCS Technical Guide Standards and Specifications for guidelines to the potential natural plant community for a specific range site and vegetation zone. Then design the seeding mixture based on the relative frequency and occurrence of each species. If published guidelines are not available, make a survey of the kind and frequency of each major species on a similar site in climax or near climax condition in the same vegetation zone. Ideally, a different species mixture should be developed for each range site. For a practical management operation this may be difficult to achieve, because seeds of some species are not available. In evaluating the kinds and proportions of species to be included in a potential plant community, the initial array may be considered as approximate, subject to change along environmental gradients associated with differences in soil, moisture, topography, and climate. Plant community boundaries are distinct where changes in soils, topography, or moisture conditions are abrupt. Boundaries are broader and less distinct where plant communities change gradually along broad environmental gradients of relatively uniform soils and topography.

• Step 3. Use Table 6 to determine seeding rates for each species.

Table 7 provides an example of the method of calculating the seeding rate for tall, warm-season mixtures of big bluestem, indiangrass, and switchgrass on sites where these are suitable.

Table 8 provides a seeding rate for a native mixed-grass planting on a silty range site (Major Land Resource Area 55B; Fig. 1). The application of this planting plan is based on the ability of the technician to identify the range site from the soils map and in the field, to load the drill with the designated grass mixture, and to plant at the proper rate. Additional species diversity may be achieved by applying high-quality native prairie hay as a mulch to the selected areas. A protective cover is essential on sites where erosion is a problem. Companion crops are not recommended with native grass seedings.

Table 9 illustrates a similar procedure for establishing a stand of tall wheatgrass, intermediate wheatgrass, alfalfa, and sweetclover.

Seed Sources

The origin, or location where collected, of native strains or released varieties of grasses is important in determining where the plant will be adapted. Also, an understanding of the inherent variability within individual populations of a species is essential to select varieties for seeding. The USDA-SCS, in

Table 6. *Guide to seeding rates (pounds per acre) calculated on the basis of the number of pure live seeds per square foot.*

Plants	Seeds per pound[a]	Seeding rates—PLS (lb/acre)			
		10 PLS/ft²	20 PLS/ft²	30 PLS/ft²	40 PLS/ft²
Native grasses					
Big bluestem	165,000	2.6	5.3	7.9	10.6
Indiangrass	175,000	2.5	5.0	7.5	10.0
Switchgrass	389,000	1.1	2.2	3.4	4.5
Western wheatgrass	110,000	4.0	7.9	11.9	15.8
Slender wheatgrass	159,000	2.7	5.5	8.2	11.0
Thickspike wheatgrass	154,000	2.8	5.7	8.5	11.3
Streambank wheatgrass	156,000	2.8	5.6	8.4	11.2
Green needlegrass	181,000	2.4	4.8	7.2	9.6
Needleandthread	115,000	3.8	7.6	11.4	15.2
Little bluestem	260,000	1.7	3.4	5.0	6.7
Sand bluestem	113,000	3.9	7.7	11.6	15.4
Prairie sandreed	274,000	1.6	3.2	4.8	6.4
Sideoats grama	191,000	2.3	4.7	6.8	9.1
Blue grama	825,000	0.53	1.1	1.6	2.1
Reed canarygrass	553,000	0.79	1.6	2.4	3.2
Introduced grasses					
Tall wheatgrass	79,000	5.5	11.0	16.5	22.1
Intermediate wheatgrass	88,000	5.0	10.0	15.0	20.0
Smooth bromegrass	136,000	3.2	6.4	9.6	12.8
Legumes					
Alfalfa	200,000	2.2	4.4	6.5	8.7
Sweetclover	260,000	1.7	3.4	5.0	6.7

[a] Stefferud (1948).

cooperation with other agencies, has established numerous field evaluation plantings to determine the adaptation and performance of several species and selected varieties of native grass.

When strains of grasses from northern sources are moved southeastward from the point of origin, they mature earlier, are shorter, produce less herbage, and are more susceptible to leaf and stem diseases. When strains from southern sources are moved northward they generally mature later, are taller, and produce more herbage. Experience has shown that southern strains moved too far north may not be winter-hardy and may be damaged or killed during the year of establishment or under adverse conditions caused by climatic or management factors in later years.

The varieties of native plants in commercial seed production are selected to exhibit superior performance within a proven area of adaptation. The

Table 7. *Seeding rates based on pure live seeds (PLS) and bulk pounds per acre for tall, warm-season native grasses in areas of adaptation.*

Species	Optimum lb/acre PLS[a]	Percent of full seeding	Amount of PLS (lb/acre)	Seed quality[b]		Factors[c]	Bulk seed (lb/acre)
				Purity	Germination		
Big bluestem	10.6	0.50	5.3[d]	70	60	2.4	12.7
Indiangrass	10.0	0.30	3.0	75	60	2.2	6.6
Switchgrass	4.5	0.20	0.9	95	80	1.3	1.2
Totals			9.2				20.5

[a] Based on recommended full seeding rate of 40 PLS per square foot.
[b] Percent purity and germination are shown as minimum standards for good quality seed. Use actual purity and germination of seed lot to calculate bulk pounds.
[c] Conversion factor from Table 3 (Conversion factors to determine pounds of bulk seed needed for 1 pound of pure live seed).
[d] Optimum lb/acre PLS × Percent of full seeding = Amount of PLS.

Table 8. *Seeding rates based on pure live seeds (PLS) and bulk pounds per acre for mixed-grass prairie grasses on silty range site—Major Land Resource Area 55B.*

Species	Optimum lb/acre PLS[a]	Percent of full seeding	Amount of PLS (lb/acre)	Seed quality[b]		Factor[c]	Bulk seed (lb/acre)
				Purity	Germination		
Western wheatgrass	11.9	0.15	1.79[d]	85	80	1.45	2.6[e]
Thickspike wheatgrass	8.5	0.05	0.43	95	85	1.25	0.5
Slender wheatgrass	5.5	0.05	0.28	95	85	1.25	0.3
Green needlegrass	9.6	0.20	1.92	90	70	1.6	3.1
Sideoats grama	9.1	0.15	1.30	75	60	2.2	2.9
Blue grama	2.1	0.10	0.21	50	60	3.35	0.7
Little bluestem	6.7	0.20	1.34	70	60	2.4	3.2
Big bluestem	10.6	0.10	1.06	70	60	2.4	2.5
Indiangrass	10.0	0.025	0.25	75	60	2.2	0.5
Switchgrass	4.5	0.025	0.11	95	80	1.3	0.1
Totals			8.69				16.4

[a] Seeding rate is adjusted for species differences in seedling vigor and rate of establishment. Refer to Table 4 for actual rate, PLS per square foot.
[b] Percent purity and germination are shown as minimum standards for good-quality seed. Use actual purity and germination of seed lot to calculate bulk pounds.
[c] Conversion factor, Table 3 (Conversion factors to determine pounds of bulk seed needed for 1 pound of pure live seed).
[d] Optimum lb/acre PLS × Percent of full seeding = Amount of PLS.
[e] Amount of PLS × Seed quality factor = Bulk seed.

use of these superior varieties is encouraged. The alternative is to use seed harvested from natural grasslands. Purchased seed from native grassland harvests is often not identified to a specific point of origin, but if the seed can be harvested in the vicinity of the area of proposed planting it can be used locally with confidence. The area of adaptation for selected varieties of native grass species follow the principles of those of native ecotypes. Experience of the SCS (Cooper 1957) indicates that an ecotype can be moved as far as about 300 miles north or 200 miles south of its origin without having serious problems of winter hardiness, longevity, and disease. Movement of ecotypes east or west is affected by changes in annual precipitation and elevation. Generally, an increase of 1,000 feet in elevation is equivalent to a move of 175 miles north.

Guidelines in the above paragraph do not apply to introduced species but each introduced species or cultivar has a greater though definite range of adaptation (Thornburg 1981). Use of certified seeds of selected varieties known to be adapted to specific areas is recommended for the latter reasons (Table 10).

Table 9. *Seeding rates based on pure live seed (PLS) and bulk pounds per acre for introduced cool-season grasses and legume stands in all Major Land Resource Areas in the area of guidelines applicability.*

Species	Optimum lb/acre PLS[a]	Percent of full seeding	Amount of PLS (lb/acre)	Seed quality[b]		Factor[c]	Bulk seed (lb/acre)
				Purity	Germination		
Tall wheatgrass	11.0	0.40	4.5[d]	95	85	1.25	5.6[e]
Intermediate wheatgrass	10.0	0.38	4.0	95	85	1.25	5.0
Alfalfa	4.4	0.22	1.0	95	90	1.2	1.2
Sweetclover	3.4	0.15	0.5	95	90	1.2	0.6
Totals			10.0				12.4

[a] Based on recommended full seeding rate of 20 PLS per square foot.
[b] Percent purity and germination are shown as minimum standards for good quality seed; use actual purity and germination of seed lot to calculate bulk pounds.
[c] Conversion factor, Table 3 (Conversion factors to determine pounds of bulk seed needed for 1 pound of pure live seed).
[d] Optimum lb/acre PLS × Percent of full seeding = Amount of PLS.
[e] Amount of PLS × Seed quality factor = Bulk seed.

Table 10. *Areas of adaptation and performance standards for selected species and varieties of native grasses.* [a/]

Species and variety	Origin	Area and degree of adaptation in specific Major Land Resource Areas in the prairie pothole region [b/]											
		53A	53B	53C	55A	55B	55C	56	57	91	102A	102B	103
Warm-season, Native													
Big bluestem													
Kaw	Southeast Kansas	0	0	9	0	0	9	0	0	0	5-7	3	3-5
Pawnee	Pawnee County, Nebraska	9	5-7	5	9	5-7	3	5-7	5-7	5-7	3-5	1	1
Champ	Iowa, southeast Nebraska	0	0	9	0	7	5	7-0	5-7	5-7	3	1	1
PM-SD-27	Beadle County, South Dakota	7	3-5	1	5	1-3	1	3-5	5	5	1	1	3
NDG-4	Morton County, North Dakota	3	1	3	1	1-3	5	3	3	3	5-7	9	9
Sand bluestem													
Woodward	Woodward County, Oklahoma	0	0	0	0	0	9	0	0	0	0	9	9
Goldstrike	Western and north-central Nebraska	0	7	5	0	5-7	3	5-7	5-7	5-7	3	1	1-3
Garden	Nebraska	9	7	5	9	5-7	3	5-7	5-7	5-7	3	1	3
Indiangrass													
Osage	Kansas, Oklahoma	0	0	0	0	0	0	0	0	0	0	0	7
Oto	Kansas, Nebraska	9	5-7	3-5	9	5-7	3	7	7	7	3-5	1	1-3
Holt	Nebraska	7	3-5	3	7	3-5	1	3-5	5-7	5-7	3	1	1-3
Nebraska 54	Nebraska	9	7	3-5	9	5-7	3	5-7	7	7	3-5	1	1-3
PM-ND-444	North Dakota and South Dakota	5	1-3	1	3	1	1	1-3	3	3	1	3	5
Native grasses													
Switchgrass													
Blackwell	Oklahoma	0	0	0	0	0	0	0	0	0	7	5	5
Caddo	Oklahoma	0	0	0	0	0	0	0	0	0	7	5	5
Kanlow	Oklahoma	0	0	0	0	0	0	0	0	0	9	5-7	5
Cave-in-Rock	Illinois	0	0	9	0	9	9	9	7-9	7-9	5-7	3-5	3
Pathfinder	Kansas, Nebraska	9	7	7	9	5-7	5	5-7	5-7	5-7	3-5	1	1-3
Nebraska 28	Holt County, Nebraska	7	3-5	3	7	3-5	3	3-5	5	3-5	1-3	1	1-3
Summer	Otoe County, Nebraska	9	5	3	7	3-5	3	3-5	5	5	1-3	1	1
PM-SD-149	Sanborn County, South Dakota	7	1-3	1	3-5	1-3	1	3	3	3	1	1-3	1-3
NDG-965-98	Morton County, North Dakota	3	1-3	1	1	1	3-5	1	1-3	1-3	3	5	5
Little bluestem													
Aldous	Southeastern Kansas	0	7	7	0	7	7	0	0	0	5-7	3	3-5
Camper	Kansas, Nebraska	7	3-5	3	9	3-5	3	5	5-7	5-7	3	1	3
Blaze	Kansas, Nebraska	7	3-5	3	7	3-5	3	3-5	3-5	3-5	3	1	1
Prairie sandreed													
Goshen	Wyoming	5	5	5	7	5	3-5	7	7	9	3	5	5
PM-ND-95	North Dakota	1	1	1	3	3	3-5	5	5	5-7	5	7	9
Sideoats grama													
Trailway	Nebraska	9	5	3-5	9	3-5	3	5-7	5-7	5-7	1-3	1	1-3
Butte	Nebraska	9	5	3	9	3-5	1	5	5	5	1	1	1-3
Pierre	South Dakota	7	1-3	1	5	3	1	3	3-5	3-5	1	1	3-5
Killdeer	North Dakota	1	1	1	1	1	3	3	3-5	3-5	5	5-7	7
Blue grama													
Lovington	New Mexico	0	0	0	0	0	0	0	0	0	0	0	0
Cool-season, Native													
Western wheatgrass													
Arriba	New Mexico	0	0	0	0	0	0	0	0	0	0	0	0
Barton	Kansas	0	7	7	9	9	7	9	9	9	7	5	7
Flintlock	Nebraska	0	5-7	1	9	5-7	1	5	5	7	3	1	3
Mandan-456	North Dakota	1	1	1	1	1	3	3	3	5	5	7	9
Rosanna	Montana	1	1	3	3	3	5	5	5	7	7	9	0
Green needlegrass													
Green Stipa	North Dakota	1	1	1	3	1	3	3	5	5	5	7	9
Lodorm	North Dakota	1	1	1	3	1	3	3	5	5	5	7	9
PM-SD-93	South Dakota	5	3-5	3	7	3-5	3	7	7	7	5	5	5-7
Thickspike wheatgrass													
Critana	Montana	1	1	5	3	3	5-7	5	7	7	5	9	9

[a/] Refer to Fig. 1.

[b/] Codes for adaptation are defined as follows: 1—Climatically adapted with optimum level of performance; 3—Good adaptation within 250-300 miles of origin; 5—Moderately adapted within 300-500 miles of origin; 7—Poorly adapted. Southern sources that are moved north-northwest are subject to severe winter injury during establishment, mature late, and will not make seed within normal growing season. Northern sources that are moved southeast mature early, have poor vegetative production, and are less disease resistant; 9—Very poor; use is not recommended; and 0—Not adapted.

Periodic Rejuvenation of Seeded Grasslands

Seeded grasslands composed of introduced cool-season grasses and legumes or native grasses must be periodically rejuvenated to maintain their optimum vigor. This is due to a condition, commonly described as "sod-bound," that is related to nitrogen deficiency (Canode 1965). Methods used to rejuvenate seeded grasslands can be natural, chemical, or mechanical. Fire and grazing are natural phenomena that rejuvenate native vegetation, and they can also be used in some cases to stimulate the height and density of introduced grasses and legumes. Mechanical methods include discing, spiking, chisel-plowing, or shallow moldboard plowing. If tillage practices are used, they should be followed by harrowing to smooth the surface of the field. Chemical fertilizers can be used to supply essential plant nutrients.

Fire may be used to enhance establishment and, on a periodic rejuvenation schedule, to increase vigor of both cool- and warm-season native grass stands. Preferred times to burn in central North Dakota are as follows. Cool-season native species should be burned in the period between late March and mid-May or from 15 August to 15 September. Warm-season natives should be burned between 15 May and 15 June. Introduced cool-season grasses and legumes should be burned between 15 March and 15 May. Early fall burns might benefit pure stands of introduced cool-season grasses but our experience has shown that fall burns usually reduce or completely eliminate alfalfa and sweetclover in mixed stands in central North Dakota. Increased height and density of introduced grasses as a result of prescribed burning usually last for only a few years. Few burns on native seedlings have been evaluated but effects of fire on true native grasses may last for a longer period of time.

Chemical fertilizer may be used to stimulate seeded grassland stands after establishment (Lavin 1967). As a general rule, nitrogen (N) promotes growth of grasses and phosphorus (P) promotes legumes. Trials in central North Dakota on 6-year and older mixed stands of alfalfa and smooth bromegrass indicated that treatments of less than 100 pounds of N per acre provided increased plant height during 1 or 2 years, whereas application of 250 to 600 pounds of N enhanced grass height for 3 to 6 years, usually in direct relationship to the amount applied (K.F. Higgins, unpublished data). Generally, less P (10 to 15 pounds per acre) is needed on seeded grasslands unless enhancement of legumes or other forb species is desired.

Rejuvenation treatments of native grass seedings after their establishment should be limited to fire, grazing, or haying. Fire is the preferred method unless it cannot be used because of strong social or economic reasons. Generally, these treatments should be applied within a period of a few days. Check local sources for approximate dates. Grazing or haying should not be used on an annual basis on areas managed for optimum wildlife production.

Mechanical treatment (tillage) is the best method for periodically rejuvenating introduced cool-season grasses and legumes such as intermediate wheatgrass, tall wheatgrass, smooth bromegrass, alfalfa, and sweetclover. Trials in central North Dakota involving mowing and mechanical scarifications of grass-legume stands resulted in the conclusion that mowing produced a positive effect on vegetative vigor during the first growing season following treatment and usually favored legumes (K.F. Higgins, unpublished data). Effects from mowing during the second or later growing seasons were not very apparent. Mowing does not remove the lower litter layer and a long-lasting positive effect on plant development is not attained.

Mechanical scarification from either early spring or late summer treatments showed similar effects. Treatments causing the greatest soil disturbance were the most effective. In general, mechanical treatment should completely disturb the soil and plant roots to a depth of about 4 to 6 inches. Light discing or harrowing should follow spiking, chiseling, or shallow (4 inches) plowing in order to smooth the surface of the field. Removal of residual vegetation by haying, grazing, or burning is recommended just before the mechanical treatment to remove excessive plant materials that would hamper tillage operations. In some instances on public lands this removal of excessive vegetation can be done by cooperators in lieu of payment for the mechanical treatment.

Introduced cool-season grasses and native grasses in seeded stands should be watched for signs of vegetative deterioration since seeded vegetation requires rejuvenation to maintain a vigorous condition. Frequency of rejuvenation will vary according to site, success of establishment, soil fertility, moisture, plant species, and other factors. For most areas in the prairie pothole region, we believe the interval of rejuvenation treatments for seeded grasslands may be 5 to 10 years, but it is not possible to prescribe exact schedules. Prescribed burning or a planned grazing system, or a combination of burning and grazing, appear to be methods most suitable for the rejuvenation of seeded native grasses. The best stands of introduced grasses and legumes are maintained by reseeding after a treatment of complete tillage and 1 or 2 years of crop production.

Seeded native grasses should be considered as permanent cover and introduced grasses as semipermanent cover.

Summary and Conclusions

It is possible to establish good stands of grassland using either introduced grasses and legumes or native grasses if proper attention is given to site selection, site preparation, planting methods, and other details outlined in this publication. However, failure to follow the proper procedures will usually result in a poor stand. Some factors are under man's control and some, such as soil phase and climate, obviously are not. Nevertheless, these natural factors make up the potential of a site to produce vegetation, and this fact should be clearly recognized. Cultural practices, especially seedbed preparation and seeding technique, are very important in attaining a good stand of grass. Managers have the capability of controlling these factors and should do so. Unfortunately, a lot of high-priced seed has been wasted on poorly prepared seedbeds.

If a planting fails, do not hesitate to cultivate and reseed if it is probable the soils and climate can produce a better stand. A good stand is usually apparent by the first or second year after seeding. Most grass plantings on cropland will contain many weed competitors the first year. If the competition is by annual plants, there is little problem. Although seeded perennials will usually overcome annuals by the second or third year, the problem is much more serious if the stand has an abundance of undesirable perennial grasses or forbs, and many inferior plantings result because of such competition. Warm-season native grasses are especially poor competitors with annual weeds.

Establishment and maintenance of high-quality stands of seeded grassland can be an important wildlife management activity. The need for good management of areas dedicated to wildlife is emphasized by the destruction and degradation of grassland habitats on private lands. We believe this publication should be updated as new knowledge is obtained by wildlife managers and researchers and agricultural agencies.

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