TECHNICAL NOTES

U. S. DEPARTMENT OF AGRICULTURE SOUTH DAKOTA SOIL CONSERVATION SERVICE

PLANT MATERIALS NO. 14 August 21, 1978

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Range Conservationist

The attached pamphlet, "Tolerance of South Dakota Plants to Flooding and to Wet Soils," is intended to bring together, and thus make available, much of the research and experienced knowledge on this subject.

Additional copies of this pamphlet may be obtained from the South Dakota State Office.

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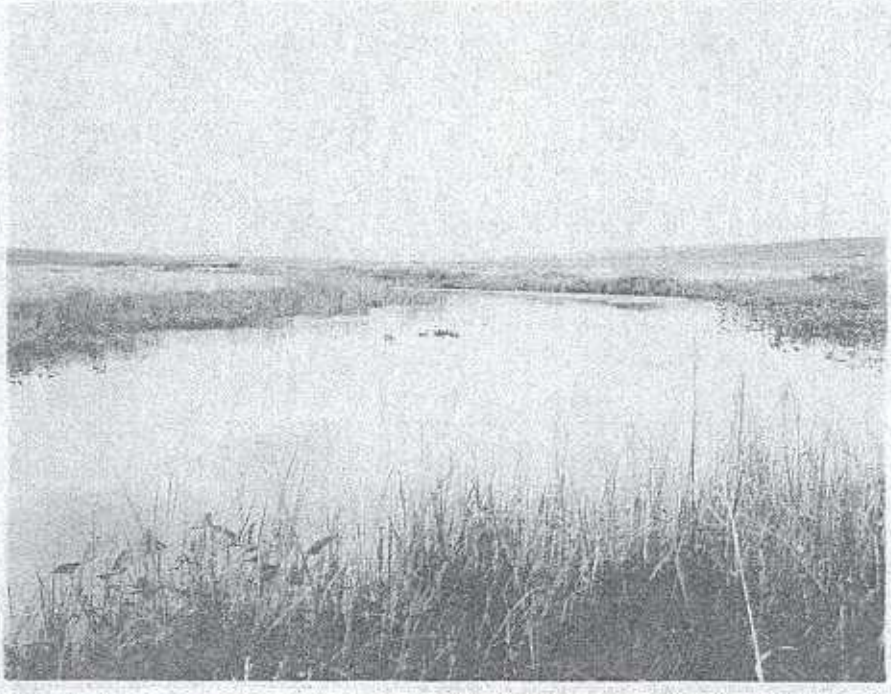
State Resource Conservationist

Attachment

File: Plant Materials Binder, Sec. 4

TOLERANCE OF SOUTH DAKOTA PLANTS TO FLOODING AND TO WET SOILS



SOIL CONSERVATION SERVICE
U.S. DEPARTMENT OF AGRICULTURE
HURON, SOUTH DAKOTA 57350

July 1978

TOLERANCE OF SOUTH DAKOTA PLANTS TO FLOODING AND TO WET SOILS

C. M. Schumacher, Range Conservationist, SCS, Huron, SD

INTRODUCTION

Tolerance of plants to flooding and wet soils is an important consideration in several areas of resource conservation planning. This subject is discussed in the first section (General) of this pamphlet as applicable to any situation. The following three (major) sections relate to specific situations: Native Plants; Pasture and Tame Hayland; and Woody Plants. Each of these major sections is complete, with references, so may be used as separate sources of information. The source used for scientific plant names in all sections is, Van Bruggen, Theodore (1976).

The section "Native Plants" will be useful in the determination and description of range sites. The section "Pasture and Tame Hayland" will be useful when selecting species for planting on wet soils for pasture, hayland, critical area stabilization, or aesthetic purposes. The section "Woody Plants" will be useful when predicting losses that may result from temporary flooding and when selecting woody species for planting on temporarily flooded sites or wet soils.

The primary purpose of this pamphlet is to bring together, and thus make available, the research and experienced knowledge pertaining to tolerance of South Dakota plants to flooding and to wet soils.

GENERAL

For most kinds of plants, soil-water content in the proximity of field capacity is most favorable for continued growth. As soil-water content increases above field capacity, the growth of most plant species will in time be retarded as the result of an accompanying decrease in aeration of the soil. For example, when soils become waterlogged any of the common cultivated plants that are growing there will turn yellow, show wilting, and ultimately die.

Throughout time the process of natural selection, acting upon genetic diversity in organisms, has produced some plant species that are adapted to a wet habitat. These plants are called hydrophytes (water-plants) and they differ structurally or physiologically from mesophytes (middle-plants) and xerophytes (dry-plants). In the course of evolution plants have evolved that find a suitable habitat in one or the other of these soil-water relationships. No plant can become established (germinate, grow, and reproduce) in both very wet and extremely dry situations. However, once plants are thoroughly established they are able to withstand extreme fluctuations of wetness or dryness for

varied periods of time. This accounts for the occurrence of relicts of water-plants on sites that are now drier than the site on which they usually grow.

The time of year flooding occurs, especially as related to the growing season, has an important bearing on tolerance. Mesophytic plants are not adversely affected by flooding during the dormant season unless soil erosion or more than normal sediment deposition occurs. When plants are dormant the oxygen demand by roots is minimal. Another factor affecting wetness tolerance is water temperature. When water temperature rises the solubility of oxygen in the water decreases and demand for root oxygen becomes greater because of an increased respiration rate. Slow moving stagnant water is more repressive to plant growth than is moving water. Faster moving water generally has a better oxygen supply.

Structural differences, though they may not be conspicuous, are of extreme importance in determining the plant's ability to adapt itself to wet conditions. In general, plants growing in a wet habitat show the following variations from plants growing in a dry habitat.

1. They develop a shallower root system.

2. Roots are coarse and commonly without root hairs.

3. The tissue in the roots has thin walled cells and very large air spaces.

4. Stems have large internal air chambers that are important in affording aeration to the submerged parts. For example, rivergrass (Scolochloa festucacea) has been called "hollow-stem" because of the unusually large opening in the stem.

5. The stomata, those minute openings in the leaves, are more numerous in water-plants and they are nearly always open. In cattails (Typha sp.) they cannot close even when the plant is subjected to extreme wilting.

6. The nearly water-proof skinlike covering, called cuticle, is usually very thin on hydrophytes and is destitute of hairs. On xerophytes this covering is very thick and often very hairy, thus retarding water losses.

NATIVE PLANTS

Observation of native plants successfully established in wet soils provides a definite key to their water tolerance. The permanence of water — and the corresponding decrease in oxygen — is the main factor limiting establishment. Fluctuations in water depth occur, not only seasonally but cyclicly, with wet and dry climatic periods. In spite of such fluctuations the natural vegetation has reached an equilibrium that permits classification.

To better understand the occurrence and relationships of these wetland plants it is important to recognize them as stages in plant succession from open water to climax (natural potential for the climate and soil). Succession starts with open water and minute plankton communities. As silt accumulates submerged and floating plants become established and form the next successional stage. Examples of such plants are species of free-floating duckweed (Lemna sp.) and submerged species of pondweed (Potamogeton sp.). These plants are pioneers that can grow in lakes where the water is too deep for the site to support emergent vegetation. However, some of these plants, especially duckweed, also occur with emergent vegetation in marshes.

As is the case in most successional plant communities the pioneer stages consist of fewer species. These stages lack diversity and in fact a site may be dominated by a single species. As the system matures more different species come in and the more mature systems have an increasing degree of stability.

Because plant succession occurs as a continuum some of the plants in the following lists occur on more than one site. They are, however, listed only for the site where they are considered as being most typical.

MARSH

Marshes occur in deep upland depressions in glaciated areas, in cut off ox-bows on floodplains of major streams, and around some natural or artificial lakes. The soil in a marsh is covered with several inches to several feet of water during the growing season. Plants listed are those that are rooted in the soil and are emergent above the water. Softstem and hardstem bulrush can grow in as much as five feet of water. Common reed occurs in the shallowest water and cattails typically occur between the reed and the bulrushes. In South Dakota, marshes occur most frequently in the northeast and north central parts of the state. The water regime modifier, as used by Cowardine et al, USDI Fish and Wildlife Service (1977), that best describes this site is "semi-permanently flooded." Marshes are not suitable for grazing by domestic livestock and they are not a range site.

Typical Plants

Common Name	Scientific Name
Softstem bulrush	Scirpus validus
Hardstem bulrush	Scirpus acutus
Common cattail	Typha latifolia
River bulrush	Scirpus fluviatilis
Green bulrush	Scirpus atrovirens
Common reed	Phragmites australis

SHALLOW MARSH

Shallow marshes occur in upland depressions that are not as deep, or that do not receive as much water, as Marsh. They may also occur as a periphery to a deeper marsh. The soil is usually waterlogged during most of the growing season; often it is covered with as much as six inches, or more, of water until mid-summer. Studies by Smith (1973), in eastern North Dakota, show that rivergrass reaches its optimum production when growing in water that is from 3 to 9.5 inches deep in June. Shallow marshes usually dry out sufficiently to permit haying in August or September. In South Dakota shallow marshes occur most frequently in the northeast and north central parts of the state. The water regime modifier, as used by Cowardine et al, USDI Fish and Wildlife Service (1977), that best describes this site is "seasonally flooded." Shallow marshes are suitable for grazing by domestic livestock and the range site is Shallow Marsh.

Typical Plants

Common Name	Scientific Name
Slough sedge	Carex atherodes
Rivergrass	Scolochloa festucacea
Beaked sedge	Carex rostrata
Common spikesedge	Elocharis macrostachya
Giant burreed	Sparganium eurycarpum
American bulrush (3-square)	Scirpus americanus
Swamp smartweed	Polygonum coccineum
American mannagrass	Glyceria grandis
American sloughgrass (annual)	Beckmannia syzigachne
Waterplantain	Alisma plantago-aquatica
Common arrowhead	Sagittaria latifolia
Rice cutgrass	Leersia oryzoides

WET MEADOW

Wet meadows occur in shallow upland depressions in glaciated areas and on floodplains where soil in marshes has built up so that it rises above the water level. This site is a successional stage between Marsh, or Shallow Marsh, and the wet lands that support prairie cordgrass. Water may stand on this site for from four to eight weeks after snow melt or for short periods after heavy rains. In South Dakota wet meadows occur most frequently in the northeast and north central parts of the state. The water regime modifier, as used by Cowardine et al, USDI Fish and Wildlife Service (1977), that best describes this site is "temporarily flooded." Wet meadows are suitable for grazing by domestic livestock and the range site is Wet Meadow.

Typical Plants

Common Name	Scientific Name
Woolly sedge	Carex lanuginosa
Slim sedge	Carex praegracilis
Fox sedge	Carex vulpinoides
Smoothcone sedge	Carex laeviconica
Reedgrasses	Calamagrostis sp.
Reed canarygrass	Phalaris arundinacea
Fowl bluegrass	Poa palustris
Needle spikesedge	Eleocharis acicularis
Torrey rush	Juncus torreyi
Smartweeds	Polygonum sp.
False-aster	Boltonia asteroides
Panicle aster	Aster simplex
Swamp milkweed	Asclepias incarnata
Field mint (introduced)	Mentha arvensis

WET LAND

Wet lands occupied by coarse grasses occur on nearly level floodplains and on uplands that have a perched water table. Soils on these wet lands are characterized by a water table that reaches the surface for only short periods but remains within 36 inches of the surface during most or all of the growing season. Water may stand on this site but usually for only short periods after snow melt or heavy rains. These soils are drier than Wet Meadow but are still too wet, and poorly aerated, to grow corn or big bluestem. These wet lands often adjoin more mesic sites, such as Subirrigated or Overflow, on which big bluestem is dominant. Typically switchgrass and Canada wildrye, though listed for this site, occur in a transitional zone between the prairie cordgrass and big bluestem. In South Dakota such wet lands occur most frequently in the eastern and central parts of the state. The water regime modifier, as used by Cowardine et al, USDI Fish and Wildlife

Service (1977) that best describes this site is "temporarily flooded." Wet lands are suitable for grazing by domestic livestock and the range site is Wet Land.

Typical Plants

Common Name	Scientific Name
Prairie cordgrass	Spartina pectinata
Switchgrass	Panicum virgatum
Canada wildrye	Elymus canadensis
Kentucky bluegrass (introduced)	Poa pratensis
Bottlebrush sedge	Carex hystricina
Other sedges	Carex sp.
Baltic rush	Juncus balticus
Waterhemlock	Cicuta maculata
Giant goldenrod	Solidago gigantea
Jerusalem-artichoke	Helianthus tuberosa
Scouring-rush	Equisetum hyemale
Hemp dogbane	Apocynum cannabinum

SALINE SOILS

Water in most of the wet soils in South Dakota is no more than moderately saline. The plants listed for the above described sites, for the most part, thrive best in fresh or slightly saline moisture conditions. Where total soluble salts, as measured by electrical conductivity, range from 8 to 20, or more, mmhos per cm, the species that occur most frequently are salt tolerant. These sites, when grazable, are classified as SALINE LOWLAND range site. The following species are examples that occur typically in the various water regimes.

Semipermanently Flooded
(not a range site)

Alkali bulrush	Scirpus maritimus
Narrowleaf cattail	Typha angustifolia

Seasonally Flooded

Nuttall alkaligrass	Puccinellia nuttalliana
Pursh seepweed	Suaeda depressa

Temporarily Flooded

Foxtail barley	Hordeum jubatum
Alkali muhly	Muhlenbergia asperifolia
Alkali cordgrass	Spartina gracilis
Saltgrass	Distichilis stricta

Several other range sites, because of physiographic features, benefit from moisture in excess of that received as normal precipitation. These sites are more mesic than Wet Land. They do not have hydric soils and their dominant vegetation is not made up of hydrophytes.

SUBIRRIGATED

Subirrigated range site occurs on nearly level bottomland and on upland having a beneficial perched water table. The water table is within 36 to 60 inches of the surface during most of the growing season. This site often borders the Wet Land range site. The dominant vegetation is big bluestem, a mesophyte.

CLOSED DEPRESSION

Closed Depression range site occurs in flat or concave bottoms of closed depressions in the central and western part of the state. This site may pond for brief periods but is not sufficiently wet for the development of hydrophytes. The dominant vegetation on this site is western wheatgrass.

OVERFLOW

Overflow range site is nearly level land that receives additional water from other lands. This site occurs throughout the state, usually on floodplains adjacent to streams. Water may stand for brief periods on this site but the vegetation is dominated by big bluestem and other mesophytes.

Illustrations are from the following publications as listed:

Wet Meadow - illustrations No. 1, 2, 3, 5, 8, 9 and 10.
Wet Land - illustrations No. 2, 3 and 5.
Saline Soils - illustrations No. 1 and 5.

These are from:

Britton, N.L. and Hon. A. Brown. 1936. An illustrated flora of the northern United States, Canada and the British possessions. The New York Botanical Garden, Bronx, New York. Three Vol. 2052 p.

We wish to thank the New York Botanical Garden for permission to use the illustrations, listed above, from Britton and Brown.

Wet Meadow - illustrations No. 4 and 6.
Wet Land - illustration No. 1
Saline Soils - illustrations No. 3, 4, 6, 7 and 8.

These are from:

Hitchcock, A.S. 1950. Manual of the grasses of the United States. U.S. Govt. Printing Office. Washington, D.C. 1051 p.

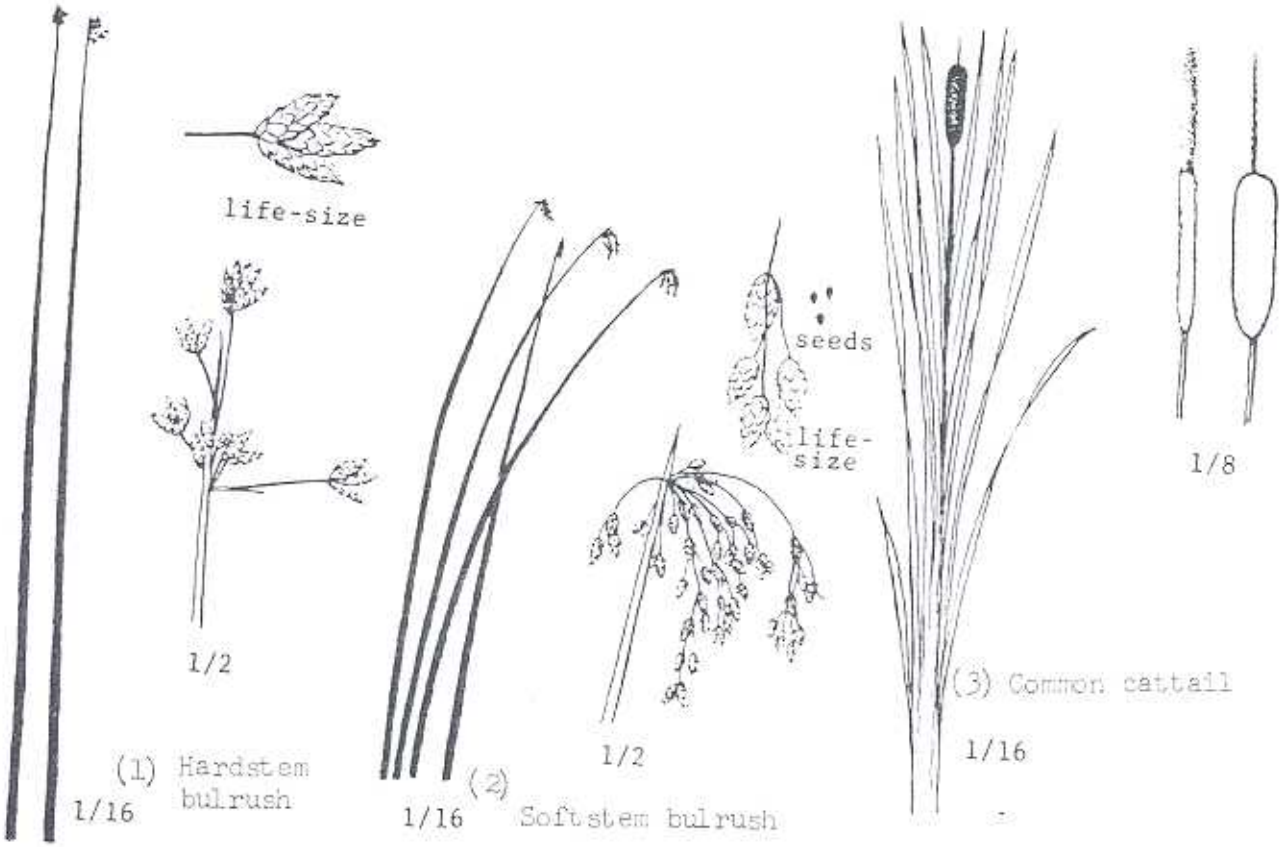
Marsh - illustrations No. 1, 2, 3, 4 and 5.
Shallow Marsh - illustrations No. 1, 2, 3, 4, 5, 6, 7, 8 and 9.
Wet Meadow - illustrations No. 7 and 11.
Wet Land - illustration No. 4.
Saline Soils - illustration No. 2.

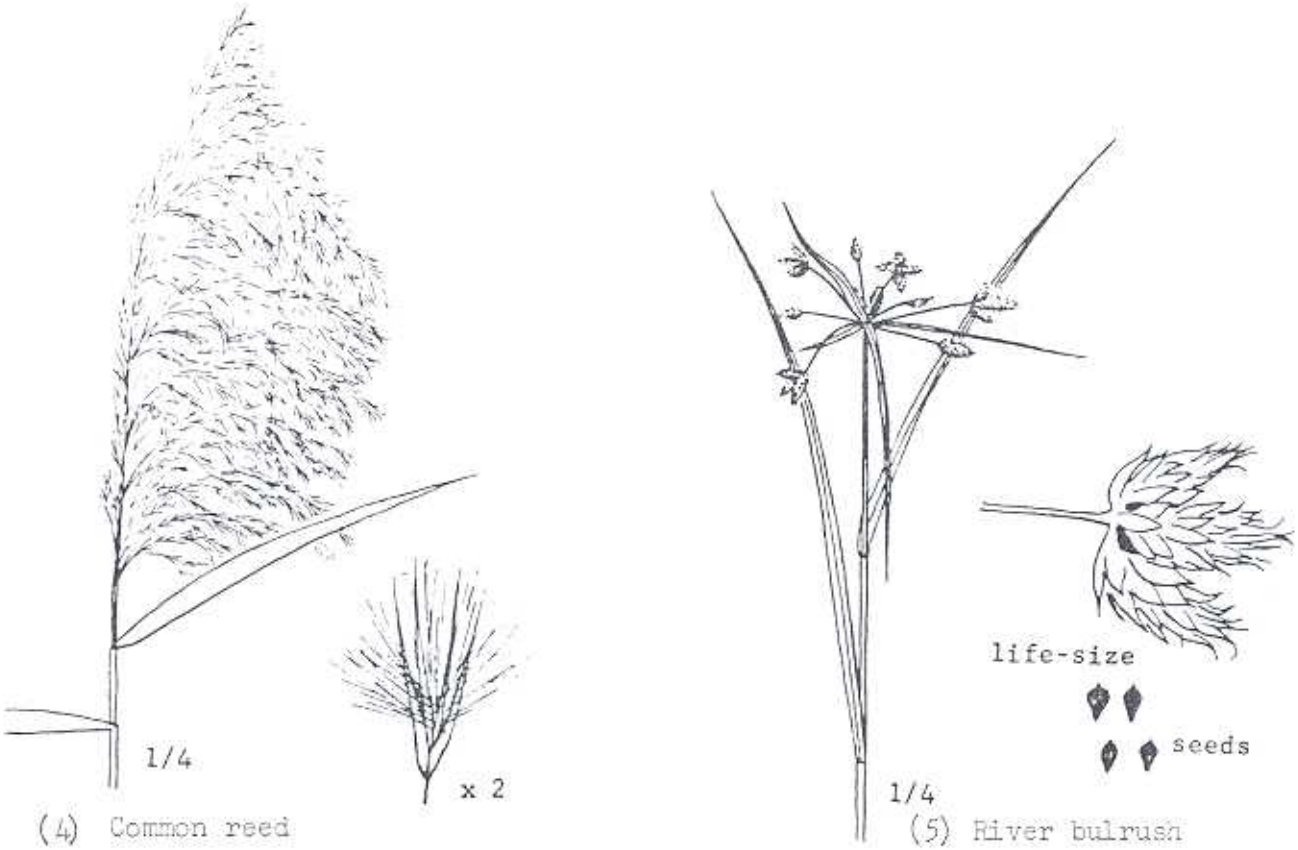
These are from:

Hotchkiss, Neil. 1970. Common marsh plants of the United States and Canada. Bureau of Sport Fisheries and Wildlife. USDI, Wash. D.C. Resource Pub. 90. 99 p.

MARSH

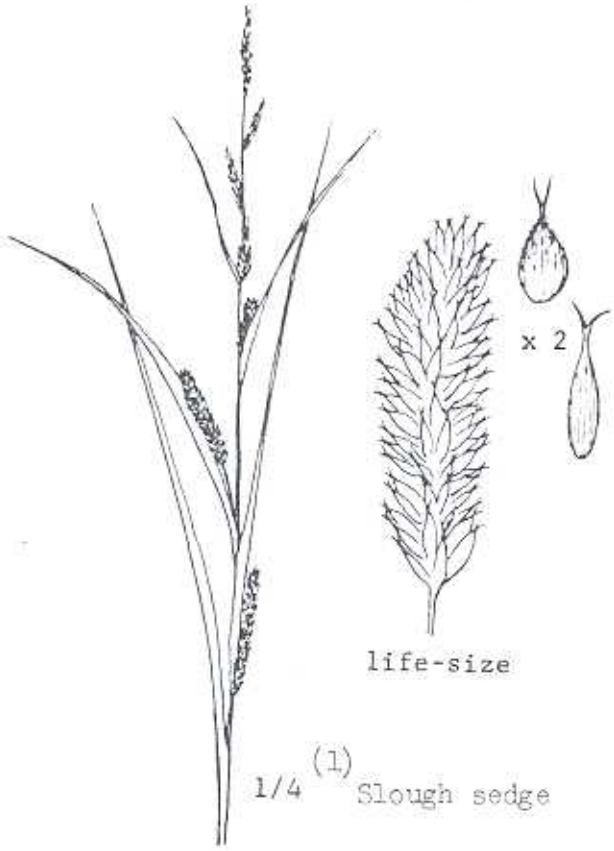
Some Typical Plants



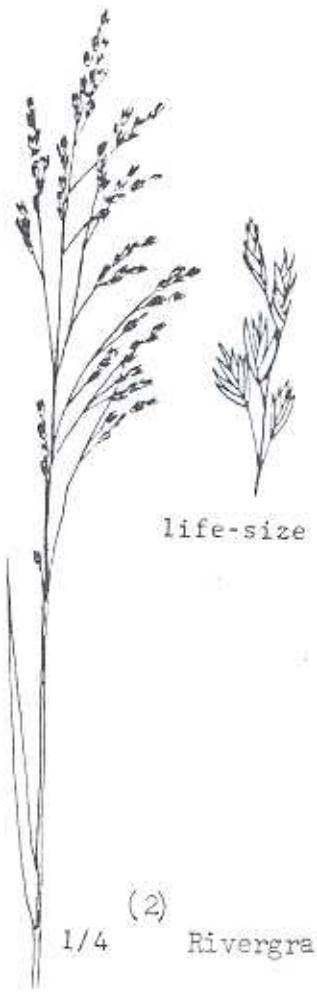


SHALLOW MARSH

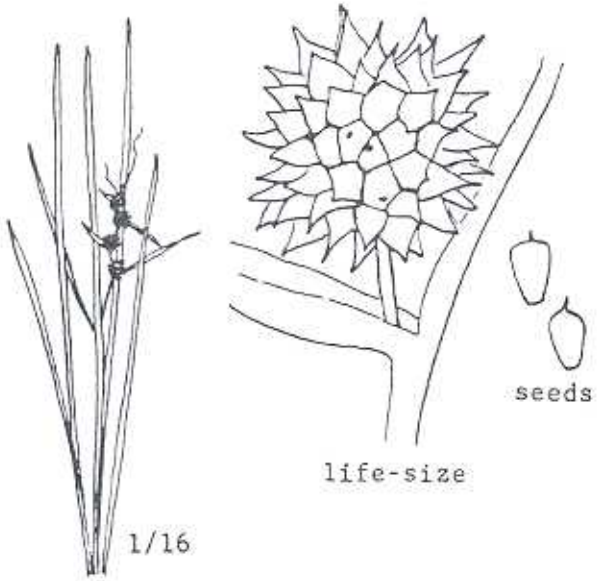
Some Typical Plants



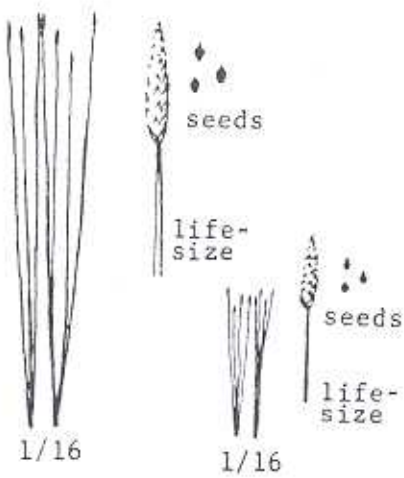
(1) Slough sedge



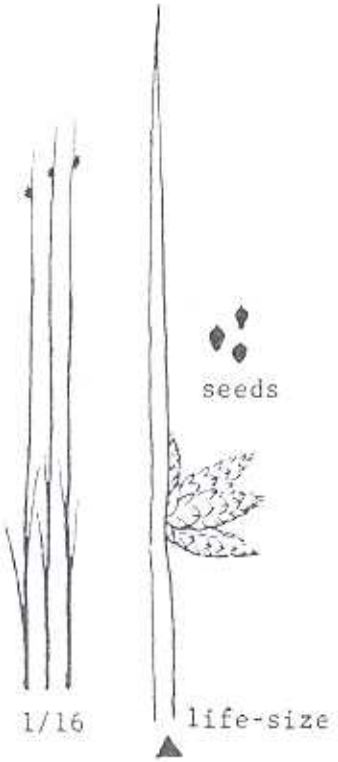
(2) Rivergrass



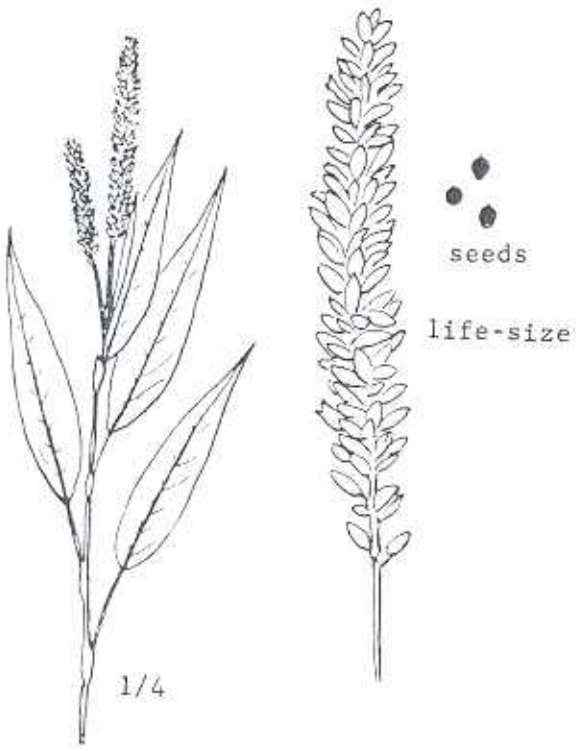
(3) Giant burreed



(4) Common spikesedge

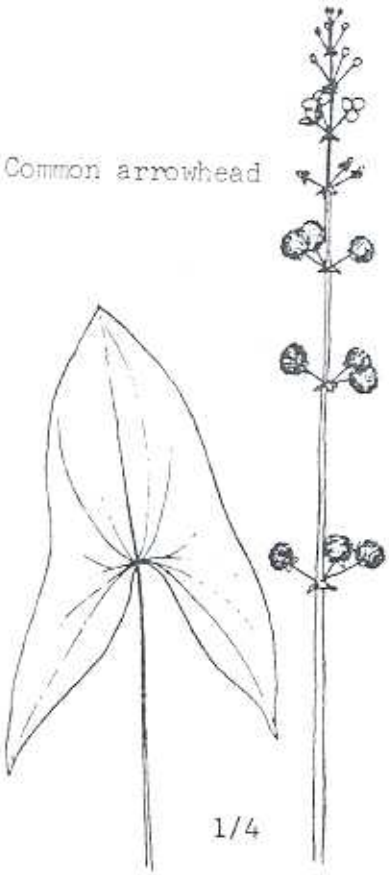


5) American bulrush



(6) Swamp smartweed

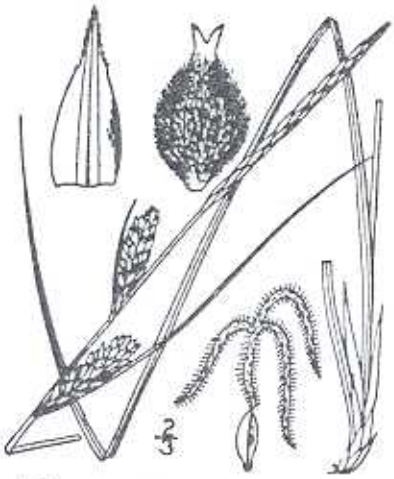
8) American mannagrass



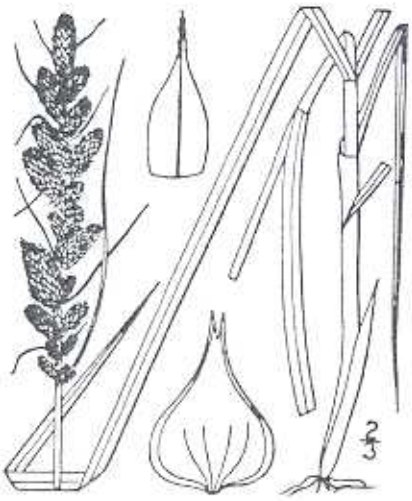
(9) Waterplantain

WET MEADOW

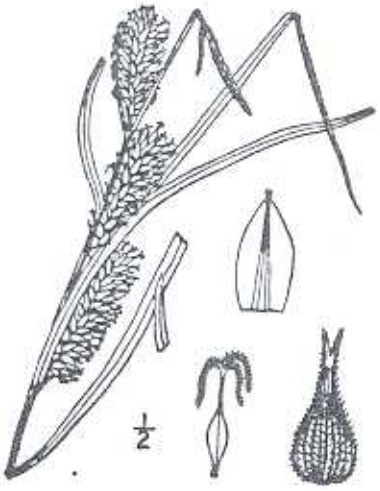
Some Typical Plants



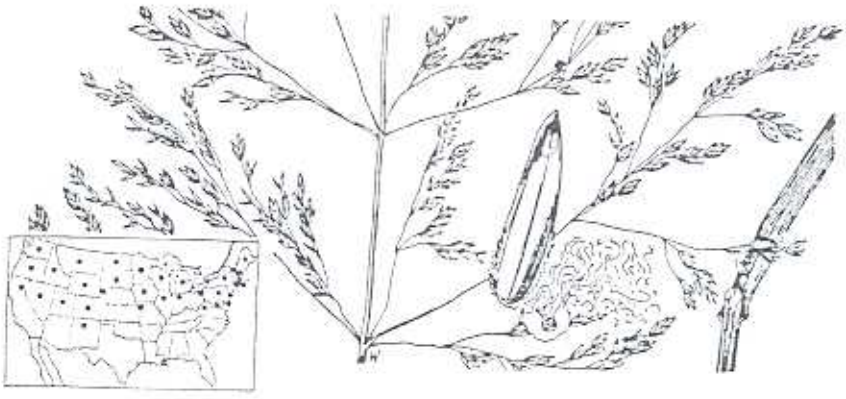
(1) Woolly sedge



(2) Fox sedge



(3) Smoothcone sedge



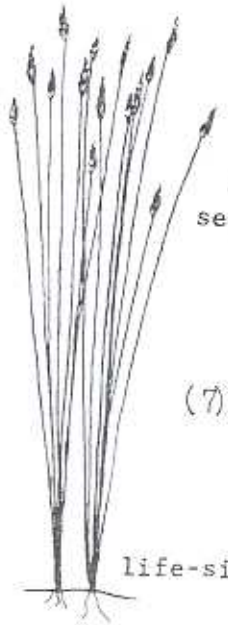
(4) Fowl bluegrass

(5) Bluejoint reedgrass

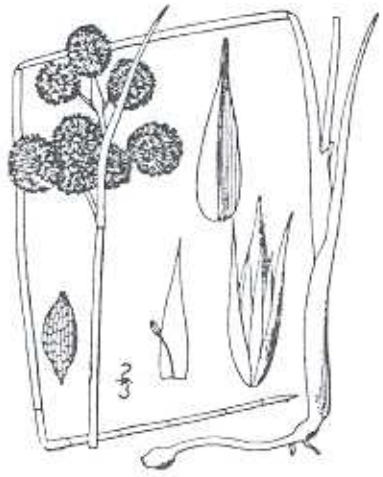
Plant, × 1;

(6) Reed canarygrass

WET MEADOW - Some Typical Plants (continued)

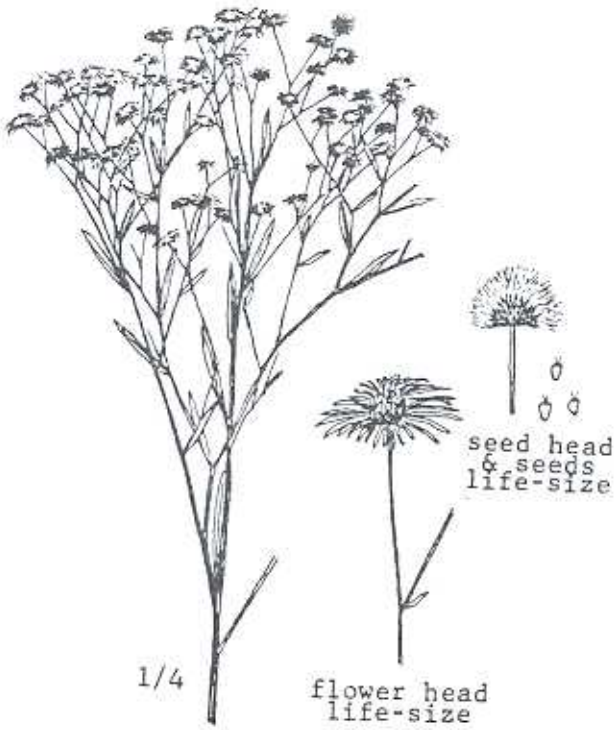


(7) Needle spikesedge



(8) Torrey rush

(9) Swamp milkweed

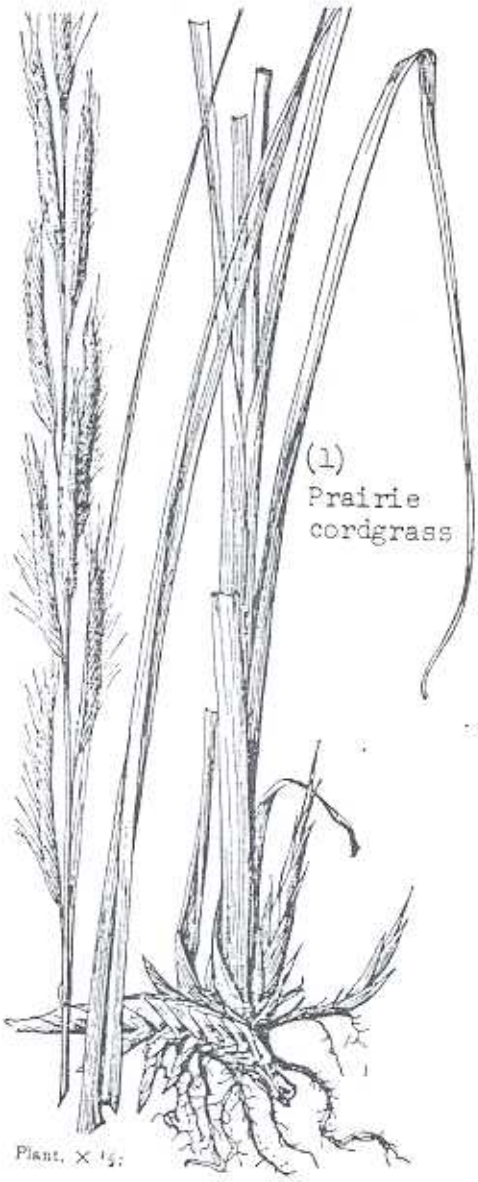


(11) False-aster

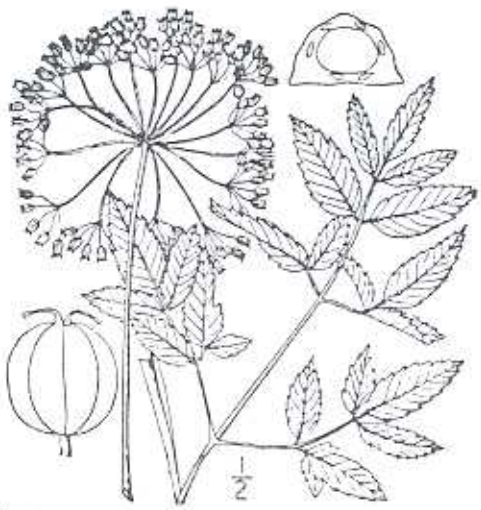
(10) Smartweed sp.

WET LAND

Some Typical Plants

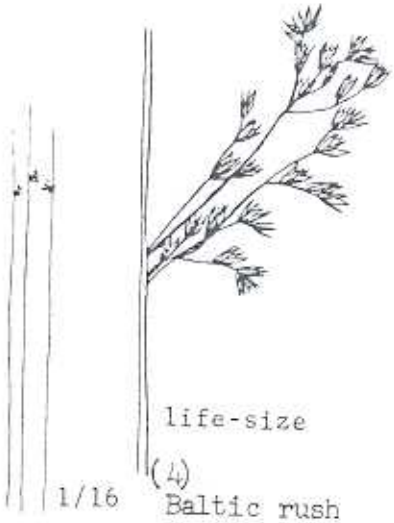


(1)
Prairie
cordgrass

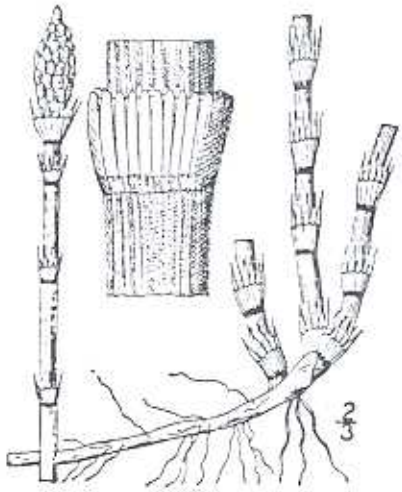


(2) Waterhemlock

(3) Jerusalem-artichoke



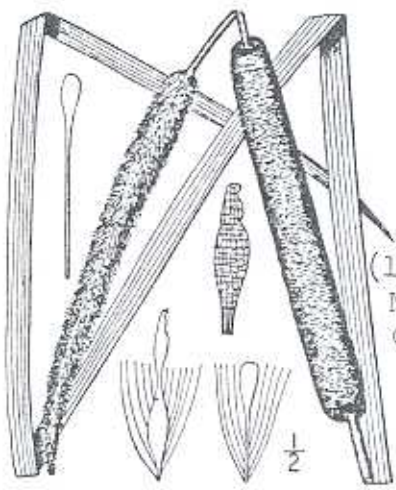
(4)
Baltic rush



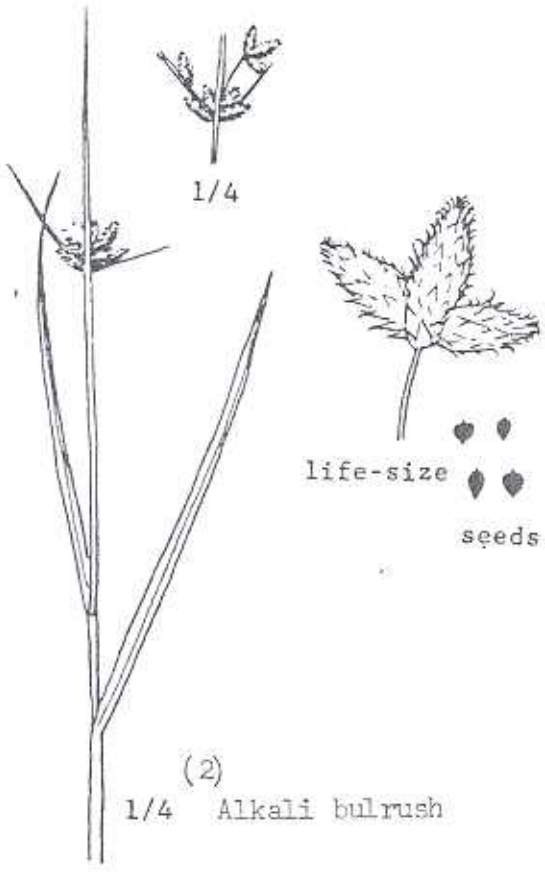
(5) Scouring-rush

SALINE SOILS

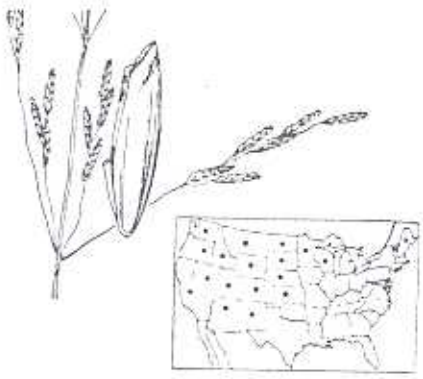
Some Typical Plants



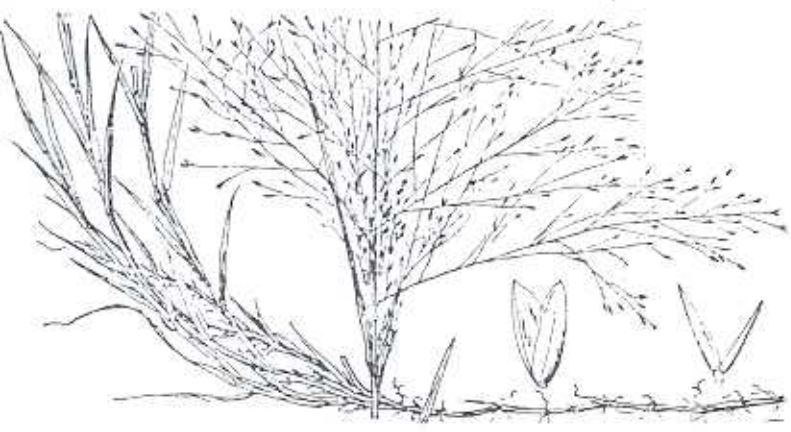
(1) Narrowleaf cattail



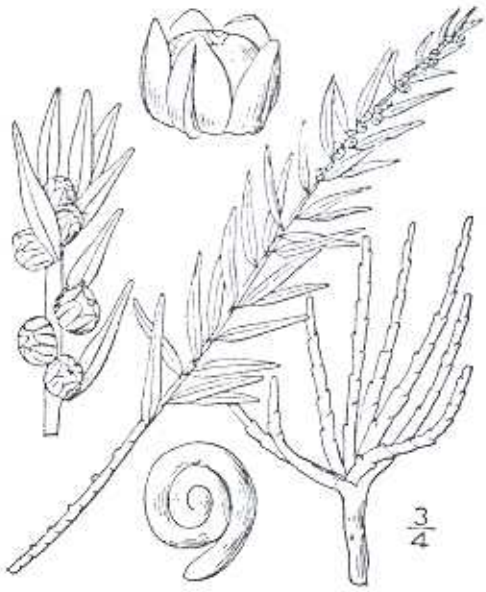
(2) 1/4 Alkali bulrush



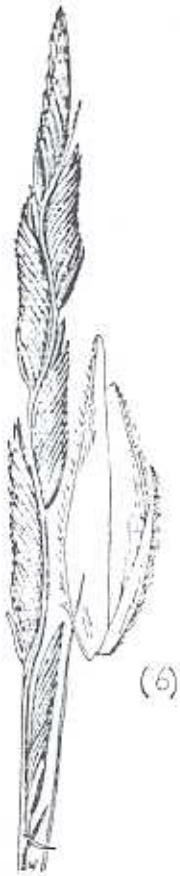
(3) Nuttall alkaligrass



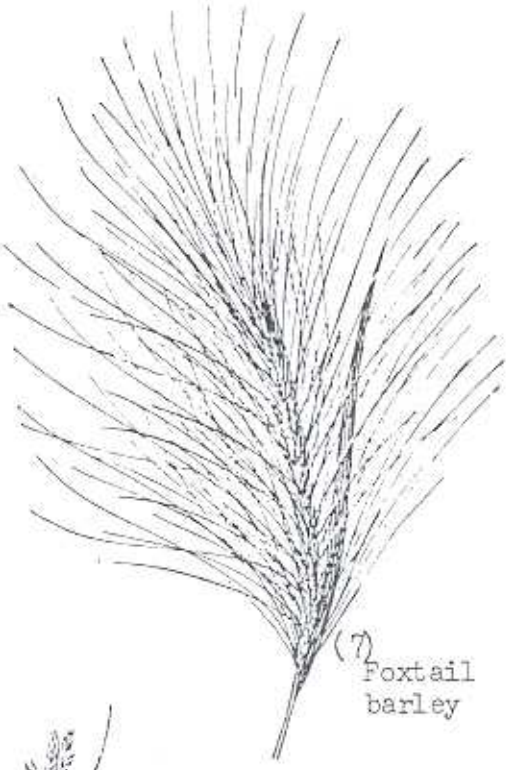
(4) Alkali muhly



(5) Pursh seepweed



(6) Alkali cordgrass



(7) Foxtail barley

(8) Saltgrass

References: Native Plants

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PASTURE AND TAME HAYLAND PLANTS

The number of pasture and tame hayland plants adapted to wet soils in South Dakota is very limited. Cultivated legumes, as a group, withstand very little flooding. Selection of species for pasture or tame hayland plantings on wet sites is thereby limited to adapted grasses. As indicated under the section Native Plants, there are several grass species that are adapted to wet soils. Most of these grasses are suited for use by grazing animals or as hay. The problem encountered when considering most of these grasses for pasture or tame hayland is the nonavailability of seed for planting. This problem reduces the number of adapted native species available for seeding on a site as wet as Wet Meadow to one species, reed canarygrass (Phalaris arundinacea). Reed canarygrass will also thrive on the Wet Land site.

Garrison creeping foxtail (Alopecurus arundinaceus), an introduced grass, has about the same adaptability for survival on wet soils as does reed canarygrass. These two species are the only hydrophytes, suited for pasture or tame hayland in South Dakota, for which seed is commercially available.

Tolerance of forage plants to spring flooding has been evaluated and reported by several authors. One such study, using many species that are adapted in South Dakota, was conducted by McKenzie (1951) near Swift Current, Saskatchewan, Canada. Results of this study are shown in Table 1.

Table 1: Range in days for tolerance to early spring flooding of grasses and legumes as mature stands, seedlings, and seeds.

Common Name	Scientific Name	Mature Plants	Seedlings	Seeds
		Days	Days	Days
*Reed canarygrass	Phalaris arundinacea	49-plus**	35-49	35-56
*Western wheatgrass	Agropyron smithii	49-63	—	—
*Slender wheatgrass	Agropyron caninum	49-63	21-35	35-56
Timothy	Phleum pratense	49-63	21-35	21-56
Meadow fescue	Festuca pratensis	35-63	49-63	21-42
*Virginia wildrye	Elymus virginicus	35-49	21-35	35-56
Tall wheatgrass	Agropyron elongatum	35-49	21-35	35-56
Red fescue	Festuca rubra	21-35	21-35	—
Russian wildrye	Elymus junceus	21-35	21-35	21-35
Intermediate wheatgrass	Agropyron intermedium	21-35	14-21	21-28
Smooth brome	Bromus inermis	24-28**	49-63	35-56
Orchardgrass	Dactylis glomerata	14-21	—	—
Alsike clover	Trifolium hybridum	14-21	—	7-14
Alfalfa (Ladak)	Medicago sativa	14-21	—	7-14
Crested wheatgrass	Agropyron cristatum	10-17**	—	—
White sweetclover	Melilotus albus	10-14**	—	7-14
Red clover	Trifolium pratense	7-14	—	0-7

*Grasses marked with * are native plants.
**Indicates data from Bolton & McKenzie (1946).

A study of grass survival in floodwater detention pools was reported by Gamble and Rhoades (1964). This study extended throughout Oklahoma and adjacent parts of Texas. Their report shows the average time grasses could be expected to satisfactorily survive inundation with cool water during the spring. Results from this study, for species that may be expected to grow in South Dakota, are shown in Table 2.

Table 2: Spring Inundation Tolerance of Selected Species:

Species		Average Number Days
Common Name	Scientific Name	of Inundation
Buffalograss	Buchloe dactyloides	45-90
Western wheatgrass	Agropyron smithii	30-60
Barnyardgrass (annual)	Echinochloa crusgalli	30-60
Virginia wildrye	Elymus virginicus	20-45
Switchgrass	Panicum virgatum	15-30
Tall fescue (introduced)	Festuca arundinacea	10-20
Indiangrass	Sorghastrum nutans	7-14
Big bluestem	Andropogon gerardi	7-14
Little bluestem	Andropogon scoparius	3-6

Buffalograss, as known in South Dakota, may seem out of place at the top of Table 2. However, buffalograss is a common native in the closed depressions, called "playas," that occur in the Texas panhandle. These undrained basins are usually dry and droughty but occasionally they are inundated by heavy rains and the water may stand for a considerable time. The tolerance of buffalograss is reported to be greatest when inundation occurs while the plants are dormant. However, Porterfield (1945) reported that buffalograss survived inundation for 30 days in the summer of 1941 and for 36 days in the summer of 1943. There is the possibility that this is an ecotype of the species that has evolved under these particular conditions.

Factors that cause a variation in flooding tolerance of grasses are documented by Gamble and Rhoades (1964) as they report on a controlled inundation study made near Chickasha, Oklahoma.

1. Tolerance differences between species:

   Prairie cordgrass was not damaged but big bluestem showed moderate to severe killing of top growth and occasional plants killed when flooded in mid-spring for 10 days with 2-4" of water. When flooded in late spring for 10 days with 2-4" of water prairie cordgrass was not damaged but all big bluestem plants were killed.

2. Tolerance differences within ecotypes of the same species:

   Kanlow switchgrass (a lowland selection) was not damaged when flooded in late spring for 20 days with 2-4" of water. Caddo

switchgrass (an upland selection) under the same treatment showed moderate to severe killing of top growth and occasional plants killed.

3. Tolerance differences resulting from depth of flooding:

   Big bluestem was not damaged when flooded in late spring for 10 days with 0-2" of water. When flooded in late spring for 10 days with 2-4" of water big bluestem showed moderate to severe killing of top growth and occasional plants killed. When flooded in late spring for 10 days with 4-6" of water all big bluestem plants were killed.

4. Tolerance difference resulting from season of flooding:

   Big bluestem was not damaged when flooded for 10 days with 4-6" of water in the early spring. When the same treatment, depth and duration, was delayed until mid-spring a majority of big bluestem plants were killed. When the same treatment was delayed until late spring all big bluestem plants were killed.

5. Tolerance differences resulting from temperature of flood water:

   McKenzie (1951) reported that flooding tolerance studies were conducted on mature grass stands during two years. One year was significantly cooler than the other and plants withstood flooding for a longer period during the year in which mean temperatures were the lowest.

The variables that effect tolerance within a species, as indicated in items 2-5 above, make the development of an exact guide to flooding tolerance an impossibility. A rule of thumb guide, that may be used while keeping these variables in mind, is shown in Table 3. This guide may be used when selecting seeding mixtures for detention pools of floodwater-retarding structures where the water level will fluctuate. It can also be used when predicting survival of forage species in areas that will be subjected to temporary flooding.

Table 3: Guide to Early Spring Flooding Tolerance of Mature Pasture and Hayland Plants

Species		Duration of Early Spring Flooding Tolerated
Common Name	Scientific Name	
Reed canarygrass	Phalaris arundinacea	6-8 weeks
Garrison creeping foxtail	Alopecurus arundinaceus	
Timothy	Phleum pratense	4-6 weeks
Redtop	Agrostis alba	
Slender wheatgrass	Agropyron caninum	
Western wheatgrass	Agropyron smithii	
*Tall wheatgrass	Agropyron elongatum	
*Tall wheatgrass is also tolerant of salinity.		
Kentucky bluegrass	Poa pratensis	2-4 weeks
Intermediate wheatgrass	Agropyron intermedium	
Smooth brome	Bromus inermis	
Switchgrass	Panicum virgatum	
Russian wildrye	Elymus junceus	
Orchardgrass	Dactylis glomerata	
*Tall fescue	Festuca arundinacea	
*Tall fescue, only in southern part of S.D.		
Indiangrass	Sorghastrum nutans	1-2 weeks
Big bluestem	Andropogon gerardi	
Green needlegrass	Stipa viridula	
Alfalfa	Medicago sativa	
Little bluestem	Andropogon scoparius	1 week or less
Crested wheatgrass	Agropyron cristatum	

References: Pasture and Tame Hayland

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WOODY PLANTS

More attention by foresters in South Dakota has been given to the effects of drought on woody plants than to the effects of too much water. This seems very reasonable when comparing the less critical need for trees on waterlogged soils with the need for trees on the windswept, droughty uplands.

There are wet soils, often around manmade structures, where for aesthetic, recreational or wildlife habitat purposes it would be very advantageous to introduce trees or shrubs. For this reason a better understanding of the effects of flooding on woody plants will be of some practical value to conservationists and land managers in South Dakota.

As with herbaceous plants it is known that some woody plants tolerate longer periods of flooding than do others. For example, hardwoods (deciduous) species generally show greater tolerance than do the conifers. It is considered very probable that differences in tolerance may also occur within a species, due to genetic variation which has occurred over a considerable period of time. However, the guide developed in this paper will be confined to pointing out differences in tolerance between species.

It is equally important that other factors affecting tolerance of woody plants to flooding be considered. Some of these factors may be quite variable and difficult to predict but effects from all these factors must be anticipated.

1. Time of flooding:

   Flooding is only critical when it occurs during the growing season, unless the flooding causes severe erosion or deposition. Studies have shown this to be true both for seedlings and mature trees. For example, McAlpine (1961) reported that seedlings of tuliptree (Liriodendron tulipifera) withstood dormant season flooding very well, but died after four days' flooding in May and after three days' flooding in June.

2. Duration of flooding:

   The duration of flooding becomes critical when flooding occurs during the growing season. Studies on several reservoirs show that even the more tolerant species generally can withstand repeated flooding for only 40 to 45 percent of the growing season. Gill (1970) states that year-round root inundation can be tolerated in isolated years. The period over which flooding can occur without it resulting in critical injury is a common criteria for describing tolerance of species.

3. Depth of flooding:

Possibility of injury of woody species increases as depth of flooding progresses from soil saturation, to partial inundation, to complete inundation. Most injury is caused by saturation of the rooting zone with water. When this occurs oxygen is excluded from the root system, there may be a buildup of carbon dioxide and there may be adverse effects from toxic by-products of decomposition. As the water level rises to submerge the plant other essential functions are affected by reduced light intensity and interference with stomatal functions. The study by Hall and Smith (1955) points out that when two flood tolerant species occurring side by side are flooded the taller of the two species may survive if the top of the taller plant projects above the water.

4. Type of floodwater:

Moving water is generally less injurious than is stagnant water, because of the better oxygen distribution in the moving water. Water temperature is also a factor and as water temperature rises the danger of injury increases.

5. Age and size of plants:

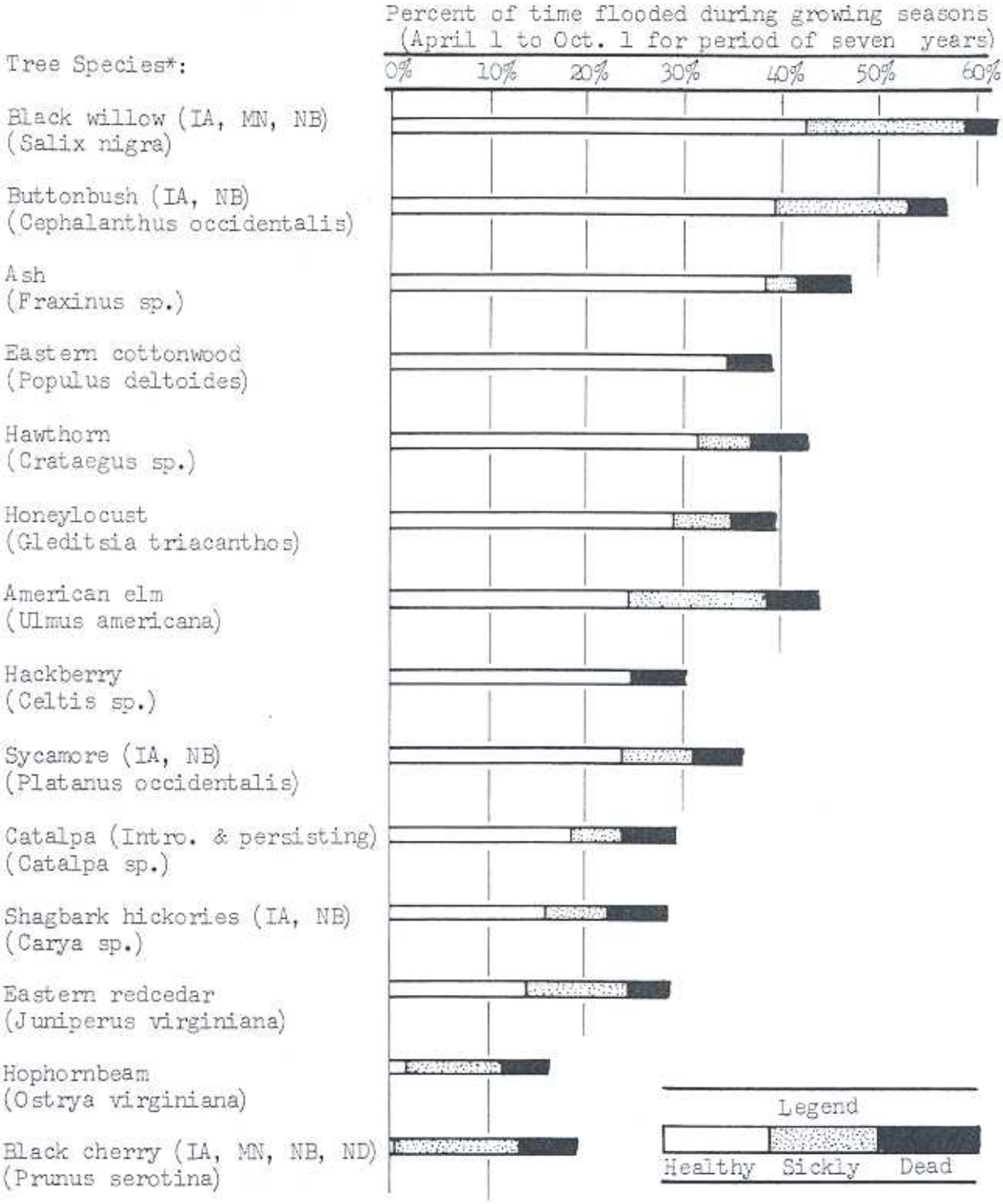
Size and, in this context, age are factors in that the shorter the plant the more apt it is to be completely inundated. Gill (1970) suggests that mature, vigorous individuals suffer less flooding damage than do either seedlings or overmature specimens of the same species.

6. Soils factors:

In general woody plants tolerate more flooding if growing on sandy soils than they do on clays. The effects of poor soil aeration are more acute on heavy soils. Because of better permeability and drainage the soil saturation effect, after flooding, is not as enduring on sandy sites. Also, plants growing on sandy soils have a much branched and well developed root system.

The differences in flooding tolerance between species have been surveyed on several flooded reservoirs. One such survey, involving many species that grow in South Dakota, was reported by Hall and Smith (1955). This study was conducted from September 1, 1944 to July 1, 1952 on the West Sandy diking and dewatering project located in Henry County, Tennessee. Tolerance was measured by correlating survival with the percent of time flooded during all of the growing seasons. The results for woody plants that grow in South Dakota, or neighboring states, are shown in Figure 1.

Figure 1. Tolerance of Woody Plants to Repeated Annual Flooding (Hall & Smith 1955) Dewatering Project in Tennessee.



*Species shown are native in South Dakota or surrounding states as indicated.

Table 1. Mortality of Trees When Flooded in Spring of 1973 (Harris 1975) Flood Pools of Lakes near Tulsa, Oklahoma

Condition of Trees After Flooding	Keystone Lake Flooded 73-83 days			Oologah Lake Flooded 67-92 days		
	Alive	Dead	Under Stress	Alive	Dead	Under Stress
Tree species:						
Willow sp. (Salix sp.)	100%	0%	0%	100%	0%	0%
Cottonwood (Populus deltoides)	100	0	0	98	0	2
Boxelder (Acer negundo)	99	1	0	97	3	0
Green ash (Fraxinus pennsylvanica)	99	1	0	94	2	4
Silver maple (Acer saccharinum)	98	2	0	--	--	--
American elm (Ulmus americana)	95	5	0	66	21	13
Hackberry (Celtis occidentalis)	91	9	0	61	13	26
Mulberry (Morus rubra)	66	22	12	80	5	15
Hawthorn sp. (Crataegus sp.)	69	18	13	—	—	—
Catalpa (Catalpa speciosa)	--	—	—	60	30	10
Redcedar (Juniperus virginiana)	45	55	0	--	--	--
Honeylocust (Gleditsia trianthos)	—	—	—	43	55	2
Black locust (Robinia pseudoacacia)	0	95	5	6	94	0

Another study, by Harris (1975), was made following a 1973 spring flood of flood pools behind two structures put in by the U. S. Army Corps of Engineers in the mid-1960s. These flood pools, both near Tulsa, Oklahoma, were flooded for the first time in 1973. Flooding started in early spring and water in the lakes returned to normal level by the middle of June. Mortality of trees was determined from normal lake level to a height 10 feet above normal lake level. At Keystone Lake the duration of flooding was 73 days at the 10-foot level and water receded to normal pool level in 87+ days. At Oologah Lake the duration of flooding was 67 days at the 10-foot level and water receded to normal pool level in 92+ days. The mortality, as determined for species of trees that grow in South Dakota, is shown in Table 1.

A guide to flood tolerance of woody plants can also be developed by observing plant distribution on flood plains and around the lakes and marshes in South Dakota. For example, the dead snags of both young and mature trees behind the Missouri River dams testify to the fact that total submergence for several years is fatal. With a knowledge of flood plain species, and observation of the habitat in which they grow, a flood tolerance grouping, shown in Table 2, has been developed.

Table 2. Natural Occurrence of Woody Plants on South Dakota Flood Plains

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1. Flooding is most frequent and of very long duration:

   a) Shrubs that grow along streams, lakes and marshes or in wet meadows.

Sandbar willow	Salix exigua
Bog willow	Salix candida
Diamond willow	Salix rigida
Meadow willow	Salix petiolaris
Indigobush	Amorpha fruiticosa

   b) Occurring where wetness is slightly less than (a) are tree willows and woody vines.

Peachleaf willow	Salix amygdaloides
Riverbank grape	Vitis riparia
Poisonivy	Toxicodendron rydbergii
Virginia creeper	Parthenocissus quinquefolia

2. Flooding is less frequent and of shorter duration - duration may still be classified as very long (more than one month):

   a) Occurring on sandy soils that may have a high water table.

Eastern cottonwood	Populus deltoides
Redosier dogwood	Cornus stolonifera

   b) Occurring on less sandy soils which do not have such a high water table.

Boxelder	Acer negundo
Green ash	Fraxinus pennsylvanica
Pricklyash	Zanthoxylum americanum
Wild rose	Rosa arkansana
Gooseberry	Ribes missouriense
Bittersweet	Celastrus scandens

   c) Introduced species that tolerate this degree of flooding.

White poplar	Populus alba
Lombardy poplar	Populus nigra

3. Flooding is occasional and duration is for a long period.

   a) Occurring on moderately well drained flood plains.

American elm	Ulmus americana
Slippery elm	Ulmus rubra
Hackberry	Celtis occidentalis
American plum	Prunus americana

   b) Introduced species that tolerate this degree of flooding.

Russianolive	Elaeagnus angustifolia

4. Broad flood plains that are occasionally flooded for long periods (7 days to 1 month) but where soils are richer, more mature, and better drained.

Honeylocust	Gleditsia triacanthos
Black walnut	Juglans nigra
Kentucky coffeetree	Gymnocladus dioica
Silver maple	Acer saccharinum
American linden	Tilia americana

5. Species which in eastern South Dakota are more apt to occur on steeper slopes and sides of ravines but further west may occur on flood plains.

Bur oak	Quercus macrocarpa
Eastern redcedar	Juniperus virginiana
Buffaloberry	Shepherdia argentea
Western snowberry	Symphoricarpos occidentalis
Smooth sumac	Rhus glabra

Using the data shown in Figure 1 and Table 1 and the observations presented in Table 2 as guidelines, it should be possible to select species that will tolerate predicted amounts of flooding. This will be of value when planning tree and shrub plantings made for aesthetic, recreational or wildlife habitat purposes in flood plain or flood pool areas..

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