TECHNICAL NOTES

.S. DEPARTMENT OF AGRICULTURE NEVADA NATURAL RESOURCES CONSERVATION SERVICE

December 1, 1995

TN - PLANT MATERIALS - 40

SALT TOLERANCE OF PLANTS

The attached Technical Note, SALT TOLERANCE OF PLANTS and the accompanying copy of publication, *Salt Tolerance of Grasses and Forage Legumes* (Agric. Bulletin No. 194) should be filed with the Plant Materials Technical Notes.

Add pen/ink entry to the Date Column (**December 1995**) and enter **Salt Tolerance of Plants** in the Title Column (for Tech Note No. 40) in the Index to Plant Materials Technical Notes.

Gary Brackley
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SALT TOLERANCE OF PLANTS

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Salt tolerance is the relative ability of a plant to produce a satisfactory yield or stand in salty soils.

SALT PROBLEMS

Saline soils commonly contain a mixture of some of the chloride, sulfate or bicarbonate and sometimes nitrate and borate salts of calcium, magnesium and sodium. Whenever either the total salt, individual salt or combination of salts in the soil is high enough to retard plant growth, injure plant tissue, and/or decrease yields, the soil is referred to as a **saline soil**.

The original source of salts is weathered bedrock and ancient saline seabottoms. Where rainfall is high, most salts are leached out of the soil. In arid regions, the salt levels accumulated in soils can be very high. However, not all soils in arid regions are saline because the soil parent materials are not always contributing sources of salts. Indirect sources of salts include irrigation water coming from saline sources upstream or water from saline groundwater wells.

Soils that are high in exchangeable sodium present a special problem in addition to those attributed to total salinity. Chemical compounds containing sodium break down soil organic matter and soil structure causing a condition termed "black alkali." The exchangeable sodium causes soil particles to disperse, resulting in smaller pore spaces. Aeration, water movement, surface crusting and root growth problems are associated with these changes in the physical condition of soil structure.

The total concentration of ions in the soil water usually has more influence in affecting plants than the precise composition of the solution. Because of this, the salinity of the soil can be determined by measuring the electrical conductivity (EC) of the soil solution. The EC is measured in millimhos/cm^3 (mmhos/cm^3) also known as millisiemens/cm^3 (ms/cm^3). One mmhos/cm^3 is equivalent to 640 parts per million (ppm) of salt.

SALINITY EFFECT ON PLANTS

As the salt content of soils increases, it becomes more difficult for plants to take up water. Sensitive plants appear drought-stricken even at fairly low levels of salt concentration. There is usually a progressive decline in growth and yields as salinity levels increase. The slower growth caused by salts may cause forage to be tougher and less palatable. This has been observed in tall wheatgrass and tall fescue. Some plants are affected by salinity more at one stage of development than at another. Barley and wheat are affected during early seedling growth but not as much during germination or later growth stages. Even when salinity decreases the plant size of barley and wheat up to 50%, little to no decline in grain yields have been noted. Corn, alfalfa and bean yields decrease almost proportionally to the decrease in plant size. Germinating sugar beets die when the salinity level is high, but mature plants are very tolerant of the same salinity level. Yield reductions are not always comparable for individual species. For example, crested wheatgrass yields are reduced 25% at 10 mmhos/cm^3, tall wheatgrass only 10% at the same levels. Yet, both species are

reduced 50% at about 20 mmhos/cm^3. Salinity problems are more severe under hot and dry conditions than under cool and humid conditions for almost all plants.
Occasionally the interaction of various salts further influences the effect of total salts. High concentrations of calcium ions in the soil solution may prevent the plant from absorbing enough phosphorus, potassium or other ions. Other ions may affect the uptake of calcium ions.

Management of Salinity Problems

Salts can be leached out of the soil if the soil permeability is good and soil is deep and does not have a water table near the surface. A good water source and good soil matrix drainage are necessary for effective salt leaching. It may be necessary to tile a field, dig drainage ditches or pump out the ground water to provide the necessary drainage. Adequate water must be applied to drain through the rooting depth of your planned crop. Continuous ponding is not as effective in removing salts and uses excessive amounts of water. Caution: Care should be taken to ensure compliance with the Wetland Provisions of FSA and FACTA. Care should also be taken to avoid contamination of ground water and surface water sources.

Seedbed preparation and irrigation management can reduce the effects of salts. Sloping beds with seed rows between the peaks or flat double row beds with a salt wick peak in the center, can cause salts to migrate away from the planted area. In addition the crowns of peaked areas can be knocked aside following pre-irrigation to remove salts that have accumulated. Planting every other row, and then irrigating every other row, will help push salts toward the non-irrigated furrow and away from the seeded row.

Saline areas with a water table can not be entered with heavy equipment during much of the year. It is however, very important that weed control and seedbed preparation are performed, whether mechanical or chemical. Weed competition and heavy trash are the biggest obstacles in seeding and establishing plant materials on saline sites. It is also very important to take advantage of organic matter (weeds or not), particularly if salinity/sodicity is associated with a high water table. The growing plants act as a biological pump, keeping the water table far enough below the surface to decrease capilarity and therefore evaporation and salt deposition on the soil surface. The roots and stems of even chemically controlled plants, assist with soil structure, infiltration and percolation of moisture through the soil profile. Mechanical tillage can destroy organic matter, vegetation and soil structure, retards infiltration and may cause salt accumulation on the soil surface. An ATV four-wheeler equipped with spray equipment can enter wet sites earlier in the spring than heavy equipment and may be the best alternative to control weed competition and maintain soil structure if available.

The optimum period to complete seedings for forage and cover type species in wet-saline soils is late fall (mid October to November) or during a snow-free period during the winter. The seed should be in the ground before the growing season begins at a planting depth of about one-fourth to one-half inch in a firm, weed-free seedbed. If followed by a moist spring, surface salts are diluted at time of germination and establishment rates are improved. Light, frequent irrigations also improve germination and establishment conditions.

Every saline site is unique in the kind and amount of salt, soil type, available moisture and climatic conditions. Most soil amendments will not correct a high salt concentration problem. A proper soil analysis (surface 6 inches), will help determine the nature of the problem and if soil amendments can be recommended.

Soils with ECs greater than 25 mmhos/cm^3 or Sodium Adsorption Ratios (SAR) in excess of 12 in high salinity soils, or 25 in low saline soils, should not be seeded until amendments, leaching or drainage has reduced the hazard. Insufficient leaching after the use of a soil amendment may make a salinity problem worse.

PLANNING A SEEDING

Salinity/sodicity soil assessments must be made prior to selection of site treatment alternatives. It is impractical to recommend a universal mixture covering all variables at potential planting sites. Species not only vary in their salinity tolerance, but also their ability to withstand a high water table or more droughty conditions.

The following table compares the relative salt tolerance of commercially available species. Most of these species can be seeded by themselves or in combination with additional adapted species. Beardless wildrye, tall wheatgrass and 'Newhy' hybrid wheatgrass are the most salt-tolerant species on well drained irrigated areas. Beardless wildrye, tall wheatgrass, tall fescue and western wheatgrass are the most salt-tolerant species on wet areas (sites where the water table stays within three feet of the surface the entire growing season). Meadow foxtail is moderately salt tolerant and an excellant forage on wet areas when it can be utilized. Russian wildrye, tall wheatgrass and Altai wildrye are quite drought-tolerant and perform best on drier saline areas (sites where the water table drops below three feet of the surface during the growing season, or where no water table is present). Crested wheatgrass, intermediate wheatgrass and pubescent wheatgrass are also very drought tolerant and will perform very well in drier moderately saline areas. The species listed for drier sites perform best in the 12-18" annual precipitation areas, but may be adequate in lower rainfall areas as well. For sites with higher rainfall the irrigated or wet site species are recommended.

Slender wheatgrass performs well on both wet and dry sites, but is relatively short lived (4-5 years). Yellow sweetclover performs well in moderate to low levels of salinity on drier sites, but is short lived. These species could be included in mixtures for quick establishment and cover, but will not persist over the long term. Both species could be considered as interim hay crops while soil amendments are being used or as green manure crops to improve soil tilth and organic matter, thus enabling the establishment of longer-lived species.

There are no commercially available legumes that will establish in strongly saline soils and the upper limit for establishment of legumes is about 12 mmhos/cm3.

Relative Salt Tolerance of Selected Plant Species

The salt tolerances given in this table compare the relative tolerances of various species. It provides an upper salinity limit above which plants will usually not germinate. The marginal level indicates the level at which the plants will grow with reduced yields.

Species	EC (mmhos/cm3) Marginal Level	Upper Limit	Tolerance Rating
Field Crops			
Barley (hay)	12	16	Good
Sugarbeets	10	13	Good
Safflower	7	11	Fair
Wheat	7	10	Fair
Oats	4	8	Fair
Corn	4	6	Fair
Beans	1	2	Poor
Forages - Irrigated (well drained soils or not saturated)			
Beardless Wildrye	24	28	Good
Tall Wheatgrass	22	26	Good
Newhy Hybrid Wheatgrass	21	25	Good
Slender Wheatgrass	20	24	Good
Tall Fescue	16	20	Good
Cicer Milkvetch	5	10	Fair
Orchardgrass	4	8	Fair
Forages - Wet/Saturated Sites (water table within 3 feet)			
Beardless Wildrye	24	28	Good
Tall Wheatgrass	22	26	Good
Altai Wildrye	22	26	Good
Newhy Hybrid Wheatgrass	21	25	Good
Tall Fescue	16	20	Good
Western Wheatgrass	14	18	Good
Strawberry Clover	12	16	Good
Creeping Foxtail	8	12	Fair
Meadow Bromegrass	6	10	Fair
Reed Canarygrass	3	5	Poor
White Dutch Clover	3	4	Poor
Alsike Clover	2	3	Poor
Red Clover	2	3	Poor
Ladino Clover	2	3	Poor
Forages - Dry (12-18" precipitation and water table below 3 ft)			
Russian Wildrye	20	24	Good
Tall Wheatgrass	20	24	Good
Slender Wheatgrass	20	24	Good
Crested Wheatgrass	12	16	Good
Pubescent Wheatgrass	8	12	Fair
Intermediate Wheatgrass	8	12	Fair
Smooth Bromegrass	8	10	Fair
Yellow Sweetclover	8	10	Fair
Birdsfoot Trefoil	8	10	Fair
Alfalfa	6	8	Fair
Mountain Bromegrass	5	6	Fair
Small Burnet	2	3	Poor

RECOMMENDED SEEDING RATES ON SALINE SITES

Seeding rates are for Critical Area Planting, 1.5 x normal rate

Common Name	Available Cultivars	Single Species Seeding Rate
Meadow Bromegrass	Regar	18
Mountain Bromegrass	Bromar	15
Smooth Bromegrass	Manchar	15
Reed Canarygrass	Ioreed,Rise,Palaton	8
Tall Fescue	Alta,Fawn,Kenmont,Goar	8
Creeping Foxtail	Garrison,Retain	5
Crested Wheatgrass	Hycrest,Nordan,Ephraim,Fairway, Parkway,Summit,P-27(Siberian Whtgrs)	11
Hybrid Wheatgrass	Newhy	12
Intermediate Whtgs	Rush,Greenar,Oahe,Amur,Tegmar,Reliant	18
Orchardgrass	Latar,Pomar,Paiute	6
Pubescent Whtgs	Luna,Greenleaf,Mandan,Topar,Manska	18
Slender Wheatgrass	Pryor,San Luis,Revenue,Primar	12
Tall Wheatgrass	Alkar,Jose,Largo,Orbit	18
Western Wheatgrass	Rosana,Rodan,Arriba,Barton,Walsh	17
Altai Wildrye	Prairieland,Ejay,Pearl	23
Beardless Wildrye	Shoshone	11
Russian Wildrye	Bozoisky-Select,Vinall,Sawki,Mayak, Swift,Cabree,Mankota	12
Alfalfa	Ladak,Nomad,Ranger,Trevois,Washoe	9
Small Burnet	Delar	30
Alsike Clover	Aurora	5
White Clover	Ladino,Merit,Pilgram	5
Red Clover	Kenland,Pollard,Redman,Reddy	9
Strawberry Clover	Salina,O'Connors	8
Cicer Milkvetch	Lutana,Monarch,Windsor	12
Yellow Sweetclover	Madrid	9
Birdsfoot Trefoil	Tretana,Leo,Empire,Dawn	6

Slender Wheatgrass and Yellow Sweetclover are short-lived and should be planted in mixtures only unless the planting objective is for short-term hay or pasture crops.

Alfalfa is best adapted to the edges of saline and saline seep recharge areas and should only be planted on the periphery where better soils are located and to intercept excess soil moisture.

Beardless wildrye needs overwinter seed stratification in seedbed and must be dormant fall seeded for successful germination.

The *desertorum* types of crested wheatgrass are more drought and saline tolerant than the *cristatum* types.

Newhy Hybrid Wheatgrass should not be planted below 14 inch precipitation unless irrigated.

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SALT tolerance of GRASSES and FORAGE LEGUMES

UNITED STATES DEPARTMENT OF AGRICULTURE
Agriculture Information Bulletin No. 194

CONTENTS

This bulletin—

1. *Provides information on the salt tolerance of grasses and forage legumes as an aid in selecting suitable crops for saline land.*
2. *Explains how salinity affects the growth of forage crops.*
3. *Describes how improved management can offset in part the unfavorable effects of salinity.*

Bernstein, Leon, 1915–

Salt tolerance of grasses and forage legumes. [Washington, U. S. Govt. Print. Off., 1958]

7 p. illus. 27 cm. (U. S. Dept. of Agriculture. Agriculture information bulletin no. 194)

1. Plants, Effect of salt on. [1. Salt—Effect on plants] 2. [Soil, Salts in] I. Title. (Series)

S21.A74 no. 194 633.2 Agr 58–347

U. S. Dept. of Agr. Libr. for Library of Congress 1Ag84Ab no. 194 †

Washington, D. C. Issued December 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 5 cents

SALT tolerance of GRASSES and FORAGE LEGUMES

By LEON BERNSTEIN, *Soil and Water Conservation Research Division, Agricultural Research Service*

WHAT IS SALT TOLERANCE?

It is the degree to which a crop can produce a satisfactory yield on salty land.

Soil salinity, or saltiness, is a widespread condition in arid and semiarid areas. The degree of saltiness varies from a low level that allows most crops to grow well, to levels so high that no crops at all can be grown. However, some plants can tolerate much more salt than others. It is important, therefore, to know the salt tolerance of different crops and varieties in order to plant those that will give the best possible yields under saline conditions.

In choosing a crop for saline land, factors in addition to salt tolerance must be considered. Adaptation to climatic conditions is always a critical factor and, for dryland farming, drought resistance may be important.

BN-6225

Test plots for studying the salt tolerance of grasses and forage legumes. Legumes on moderately saline plots are stunted or killed, while those on alternate nonsaline plots are making vigorous growth.

WHY ARE FORAGE CROPS IMPORTANT IN FARMING SALTY LAND?

Forage crops may be low-cost crops for marginal land.

They may improve soil structure of reclaimed land.

They may produce good yields of forage or seed on salty land, provided salt-tolerant species are planted.

Sometimes there is a definite limit to the improvement of salty lands. This is the case when salty irrigation water must be used, or when drainage, for one reason or another, cannot be improved enough to prevent some buildup of salt in the soil. Under such conditions, the grower must farm his salty land as best he can. Obviously, low-cost crops that require minimum expenditures for land preparation, fertilizer, seeding, and weed control will be the most attractive since the risk of loss will be minimized. Forage crops very often meet these cost requirements.

When salt is removed by leaching, the soil may at first tend to seal up and take water slowly. It is necessary to restore good soil structure in the desalted soil before it can grow satisfactory crops. The fibrous roots of grasses are particularly effective in restoring good soil tilth. Grasses are frequently used alone or in combination with forage legumes as the first crop following leaching and prior to planting row crops or orchards.

Since some of the grasses are very salt tolerant, they may be used as forage crops on lands so salty that few other crops would yield satisfactorily. Also, the cover provided by forage crops may be of benefit in reducing soil losses by wind or water erosion.

HOW DOES SALT AFFECT THE GROWTH OF FORAGE CROPS?

The primary effect of salt is to decrease the availability of water.

The main effect of soil salinity on forage crops is to make it difficult for the roots to take up water. The saltier the soil, the less readily available is the water. In appearance, grasses and forage legumes on salty soil are very much like plants on droughty land. They are stunted and bear small leaves that generally have a dark, blue-green color rather than the bright green of plants that have an adequate, readily available, moisture supply. Of course, if the soil water is too salty, the plants will eventually turn brown and die. This is usually the result of extreme moisture deficiency rather than any toxic effect of salinity.

Special nutritional effects may also be involved. Orchard grass, for example, suffers when calcium salts predominate in saline soil. Species also differ in their tolerance to sodium. Most grasses and forage legumes appear to be tolerant enough to sodium. Poor physical condition of sodium soils is the principal reason for crop failure. Soils high in sodium generally take water very slowly, and become hard and crusty when dry. Usually, such soils must be reclaimed before any crop can be grown successfully. Special information is available for the diagnosis and improvement of sodium-affected soil.

In testing for soil salinity where forage crops are involved, it is usually not necessary to analyze the soil for the separate salt constituents. A measure of total salinity is generally sufficient. An extract of the water-saturated soil is made, and its ability to carry an electrical current is measured. This measurement of electrical conductivity is a good index of soil salinity, and is related to the availability of water in the soil under field conditions. Salinity is generally reported in millimhos. Crop response at different salinity levels is indicated below.

Range of salinity in millimhos [1]	*Crop response*
0 to 2	Salinity effects mostly negligible.
2 to 4	Yields of very sensitive crops may be restricted.
4 to 8	Yields of many crops restricted.
8 to 16	Only tolerant crops yield satisfactorily.
Above 16	Only a few very tolerant crops yield satisfactorily.

[1] Conductivity of saturation extract (millimhos per centimeter at 25° C.).

HOW MUCH SALT CAN DIFFERENT GRASSES AND FORAGE LEGUMES TOLERATE?

Such crops can tolerate from as little as 2 to 3 millimhos, up to 12 millimhos or more.

For most of the salt-sensitive or moderately salt-tolerant species there is no "safe limit" of salinity. Yields fall off even at low levels of salinity, and the higher the salinity level, the greater is the decline in yield. Assuming that a minor decrease in yield can be accepted, the salt-tolerance limits for forage crops can be given for irrigated areas.

In the salt-tolerance list that follows, species are divided into tolerant, moderately tolerant, and sensitive groups. Within each group the species are ranked in order of decreasing salt tolerance, although a difference of two or three places in the ranking may not be significant. Thus, alkali sacaton generally produces well if salinity does not exceed 12 millimhos, but for good yields of birdsfoot trefoil, salinity should not exceed 6 millimhos. On soils high in gypsum, salinity levels at which a definite reduction in yield generally occurs are 2 millimhos higher than those indicated in the list. For example, alkali sacaton could tolerate salinity up to 14 millimhos, and birdsfoot trefoil up to 8 millimhos in soils that contain gypsum. Seed yields are usually less sensitive to salinity than forage yields. This is particularly true for the more tolerant grasses.

Good Salt Tolerance

(12 to 6 millimhos)

Alkali sacaton (*Sporobolus airoides*)
Saltgrass (*Distichlis stricta*)
Nuttall alkali-grass (*Puccinellia nuttalliana*)
Bermuda grass (*Cynodon dactylon*)
Tall wheatgrass (*Agropyron elongatum*)
Rhodes grass (*Chloris gayana*)
Rescue grass (*Bromus catharticus*)
Canada wildrye (*Elymus canadensis*)
Western wheatgrass (*Agropyron smithii*)
Tall fescue (*Festuca arundinacea*)
Barley (hay) (*Hordeum vulgare*)
Birdsfoot trefoil (*Lotus corniculatus*)

Moderate Salt Tolerance

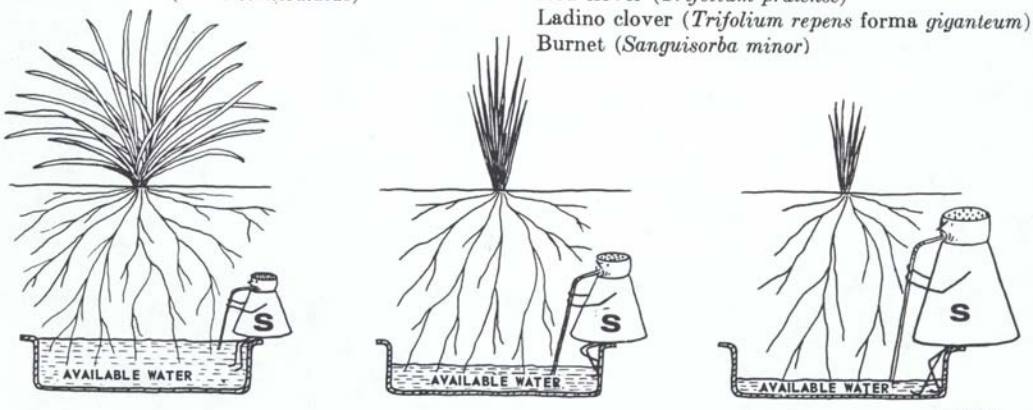
(6 to 3 millimhos)

White sweetclover (*Melilotus alba*)
Yellow sweetclover (*Melilotus officinalis*)
Perennial ryegrass (*Lolium perenne*)
Mountain brome (*Bromus marginatus*)
Harding grass (*Phalaris tuberosa* var. *stenoptera*)
Beardless wildrye (*Elymus triticoides*)
Strawberry clover (*Trifolium fragiferum*)
Dallis grass (*Paspalum dilatatum*)
Sudan grass (*Sorghum sudanense*)
Hubam clover (*Melilotus alba* var. *annua*)
Alfalfa (*Medicago sativa*)
Rye (hay) (*Secale cereale*)
Wheat (hay) (*Triticum aestivum*)
Oats (hay) (*Avena sativa*)
Orchard grass (*Dactylis glomerata*)
Blue grama (*Bouteloua gracilis*)
Meadow fescue (*Festuca elatior*)
Reed canary (*Phalaris arundinacea*)
Big trefoil (*Lotus uliginosus*)
Smooth brome (*Bromus inermis*)
Tall meadow oatgrass (*Arrhenatherum elatius*)
Milkvetch (*Astragalus* species)
Sourclover (*Melilotus indica*)

Poor Salt Tolerance

(3 to 2 millimhos)

White Dutch clover (*Trifolium repens*)
Meadow foxtail (*Alopecurus pratensis*)
Alsike clover (*Trifolium hybridum*)
Red clover (*Trifolium pratense*)
Ladino clover (*Trifolium repens* forma *giganteum*)
Burnet (*Sanguisorba minor*)



Salinity checks the growth of most forage crops.

Rhodes Grass

Perennial Ryegrass

Smooth Brome

Meadow Foxtail

BN-6226

Effect of salinity on the growth of grasses.

Some varieties of forage crops are more sensitive to salt than others. The coarse-leaved strains of smooth bromegrass are generally more tolerant than the fine-leaved strains, and some varieties of barley are more salt tolerant than others. Narrow-leaf birdsfoot trefoil is more tolerant than the broad-leaved variety. Alfalfa varieties, on the other hand, do not appear to differ appreciably in salt tolerance. For most forage species, there is very little reliable information on varietal differences in salt tolerance.

HOW DOES SALINITY AFFECT THE QUALITY OF FORAGE?

The effect varies with the species.

Some grass species take up large amounts of salt from saline soils and may become unfit for feeding. Rhodes grass, for example, may cause scours in cattle because it takes up so much salt when grown on salty lands. Since salinity checks vegetative growth, the forage may actually be richer in certain vitamins and nutrients than forage from nonsaline land. The decrease in yield, however, more than offsets the enrichment in nutrients. Furthermore, the checking of growth may cause the forage to become tougher and less palatable than forage on nonsaline land. For example, the salt-tolerant tall wheatgrass and tall fescue become tough and wiry on saline land, whereas the less tolerant perennial ryegrass remains more palatable.

HOW SHOULD THE SALT-TOLERANCE INFORMATION BE USED IN SELECTING A FORAGE CROP FOR A GIVEN SITUATION?

Salt tolerance is only one of several factors to be considered.

The State Agricultural Extension Services and the Soil Conservation Service can recommend forage species adapted to local conditions. They will take into account the temperatures during the growing season, the severity of winters and soil factors such as moisture (rainfall, irrigation), texture, fertility, and drainage. From the list of suitable forages, the individual grower can choose those which have adequate salt tolerance to produce satisfactory yields at the salinity level which he finds in his land. For example, on poorly drained, wet lands in the Mountain States, the water-tolerant strawberry clover may be preferred to the more salt-tolerant birdsfoot trefoil.

HOW CAN SALTY LAND BE MANAGED TO IMPROVE YIELDS?

Proper land leveling, leaching, irrigation, and drainage will improve yields on salty lands.

Water management is the key to salinity control. Under dryland conditions the grower can do little to remedy a saline condition except to provide for maximum penetration of rainfall by reducing runoff. Under irrigation, the possibilities for salinity control are much better. Good land leveling is essential for uniform water penetration and for preventing the buildup of salt in high spots in the field. Salts brought in by the irrigation water may tend to build up to very high levels in the soil, but adequate irrigation generally prevents such a buildup. The salt removed by leaching or heavy irrigation must eventually be carried off in natural or artificial drainageways.

Between irrigations, water is taken up by the plants and also evaporates from the soil. As a result, the water remaining in the soil becomes more and more salty. More frequent irrigation tends to keep the soil water from becoming excessively salty. Yields may often be considerably improved by frequent irrigation, provided drainage is adequate.

Because of the presence of salt, less soil moisture is available to plants. Irrigation may be required on salty soil even though the soil still has a "good" moisture content. This remaining soil moisture may be almost completely unavailable to the plants.

POINTS TO REMEMBER

1. Select salt-tolerant crops for salty land. Some grasses and forage legumes are much more salt tolerant than others.
2. Irrigate adequately to keep the salt moving down through the soil.
3. Irrigate frequently. Don't let salty land "dry out" between irrigations.

U. S. GOVERNMENT PRINTING OFFICE : 1958 O—470863