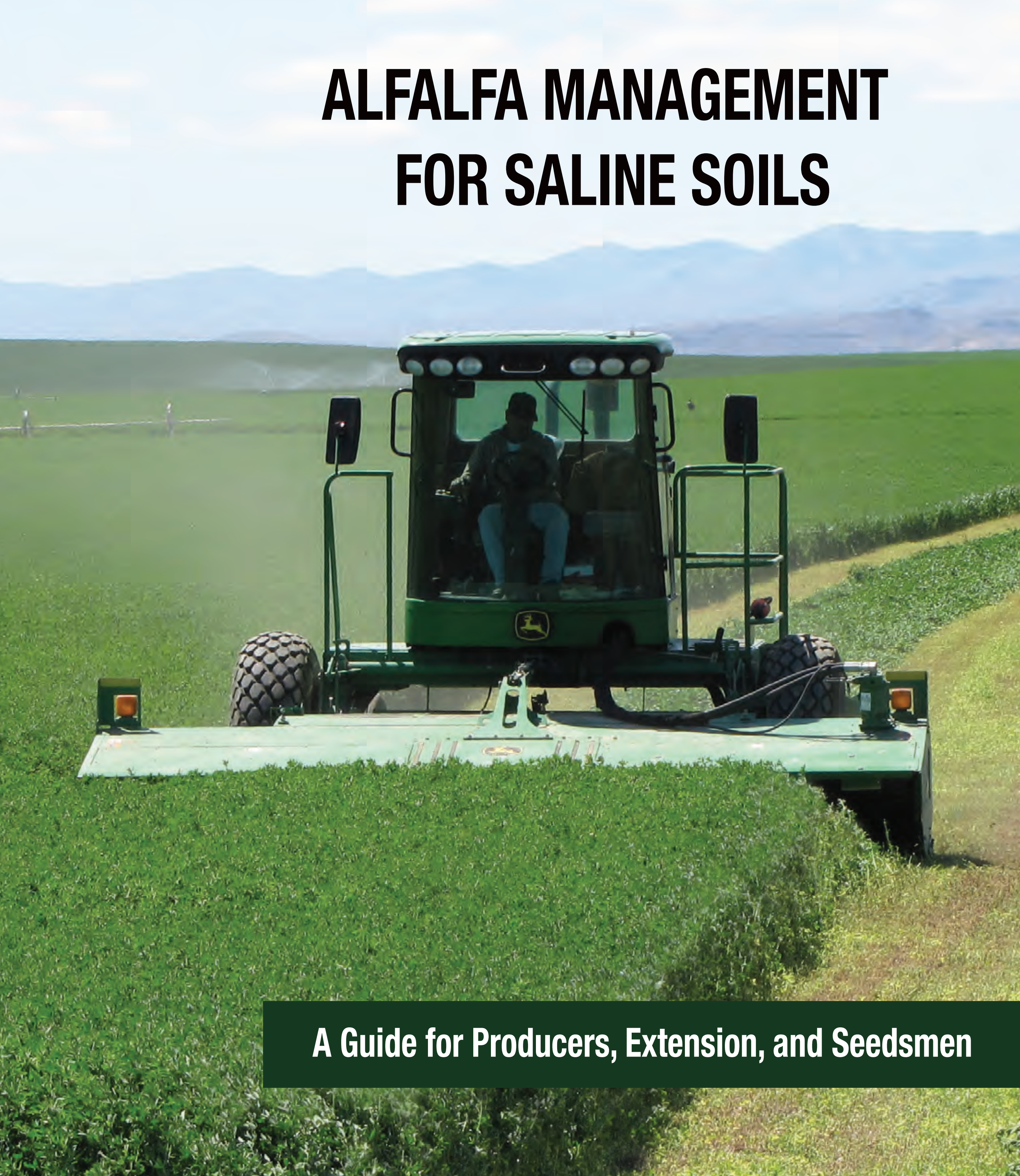
ALFALFA MANAGEMENT FOR SALINE SOILS



A Guide for Producers, Extension, and Seedsmen

Salinity is a natural byproduct of irrigated and dryland agriculture in low rainfall regions.

Alfalfa is recognized as a crop that is moderately sensitive to salinity. Despite this sensitivity, alfalfa has flourished as a major dryland and irrigated crop on 79 million acres worldwide. Twenty million acres exist across the Canadian Prairies, the western United States, and Mexico.

Over time, poor cropping practices in low rainfall regions tend to allow soluble salts to move upward in the soil profile and cultural practices such as irrigation often accelerate salinity buildup. At some point, when rainfall or irrigation are not sufficient to leach accumulating soluble salts in the soil profile out of the root zone, salinity interferes with normal crop growth and performance. The yield losses are small and negligible at first, but if left unchecked the salinity will worsen over time and eventually cause economic losses.

Fortunately, alfalfa has been very responsive to breeding efforts to improve stand establishment and yield to salinity. New varieties with enhanced salinity tolerance, when combined with proactive field monitoring and remediation practices, are the alfalfa grower's front line of defense against salinity losses.

Alfalfa Management for Saline Soils is intended to help and encourage producers in low rainfall regions around the world to:

- Better understand the science of saline soils.
- Monitor soil and water salinity conditions.
- Implement management practices to prevent, stabilize, and reduce salinity.
- Encourage the use of salinity tolerant alfalfa varieties.

Yield losses of 10-15% usually go unnoticed. The picture perfect field on the cover of this guide when tested after harvest, had salinity readings ranging from very low to high across the field. While most readings were low, the grower will monitor the salinity "hot spots" more closely.

SALINE SOILS OVERVIEW

Introduction

A saline soil is defined as one with enough salts in soil solutions to interfere with crop growth. This level varies by crop species and is most often expressed as a measurement of the electrical conductivity (ECe) of the soluble salts in the soil solution. A general definition of a saline soil is one with an ECe>4dS/m. However, alfalfa yield reductions of about 7.3% can occur for each dS/m point greater than 2.

Historic Perspective

Salinity and its detrimental effect on agriculture is not a new problem. When humans first started irrigating crops, they soon learned that long term irrigation eventually resulted in lower crop yields. History is filled with examples of once productive agricultural land that over time became marginal due to salt buildup. This ongoing problem of increasing salinity has been defined as one of the most significant problems facing modern agriculture.

Worldwide Status and Trends

It has been estimated that 10% of the total land surface in the world, or approximately 2.4 billion acres, has some form of saline affected soils, with North and South America comprising 364 million acres of that total. Salinity is reported to affect half of the world's arable land despite modern agriculture's efforts to control it. The increase in salinity is especially high in Third World countries that may lack the knowledge and resources to control. The Food and Agriculture Organization of the United Nations (FAO) and UNESCO have estimated that half of all existing irrigation systems, totaling 617 million acres, are seriously affected by salinity and water-logging with about 25 million acres of crop land being abandoned worldwide each year.

North American Status and Trends

Even in the more technologically advanced areas of the world, salinity is a growing problem, most notably on irrigated ground. It is estimated that there are 14 million acres of salt-affected soils in the United States (M. Pessarakli). According to documentation from the USDA's U.S. Salinity Laboratory, yield reductions due to salinity occur on an estimated 30 % of all irrigated land in the United States. It was estimated that in 1984 California had 10.1 million acres of irrigated farmland, of which 2.9 million had been classified as having saline soils (ECe>4). In 2000, 14 years later, it was estimated the salt-affected areas in California had increased to 3.6 million acres, an increase of 700,000 acres. The Imperial Valley of California alone has 40% of its crop acreage with ECe's greater than 4. The USDA estimates that 300,000 acres in Montana have been removed from cultivation because of salinity (J. Scianna). The U.S. states with the most salt affected acres (in millions) are: North Dakota- (9.4), South Dakota (9.1), Montana (6.9), Texas (4.5), California (3.6), Minnesota (2.8), Colorado (1.8), Idaho (1.7), Kansas (1.2), Utah (1.1), Wyoming (1.1), Nevada (0.8), Arizona (0.8), and New Mexico (0.7). It is estimated that the United States loses about 7.4 acres per day to salinization.

Saline, Alkaline, and Alkali Soils Defined

There are three distinct soil classifications that relate to the buildup of salt in soils. Knowledge of the correct soil salinity classification is critical in making the appropriate management decisions for each situation. These salinity soil types can have different effects on the water infiltration and plant growth, and will ultimately influence the short and long term management decisions for the soil.

The words saline, alkaline, and alkali are often mistakenly used interchangeably by producers when they discuss marginal soils. Saline is a soil in which soluble salts interfere with plant growth, and alkaline describes soils with a pH above 7. An alkali soil is one in which the exchangeable sodium level is high enough to interfere

Saline "White Alkali" is the most common type of saline soil found in North America and in most cases can be managed for alfalfa production.

with plant growth regardless of salinity content. The assumption that a saline soil is alkali or vice versa is not always true. In broad terms, the differences between marginal soil types are based on dissolved salts, variations in pH, and the sodium (Na) content. The basic characteristics of the three classifications are:

Saline Soil - pH <8.5 with Low Sodium (Na)<15% and ECe>4dS/m

This soil type is sometimes referred to as "white alkali" due to the white soil surface; however the term alkali does not really apply in this case since the exchangeable sodium level is low. This soil is by far the most common salinity classification found in North America. In the absence of a sodium problem, this saline soil type is somewhat easier to manage since problem salts may be leached out of the soil profile by controlling water movement. Also in the case of alfalfa, the pH is in a more acceptable range, below the upper limit for alfalfa plant growth (8.4). The majority of plant breeding efforts to improve alfalfa performance under saline stress are directed at fields with this saline soil classification.

Saline Alkali Soil (Saline Sodic) - pH < 8.5 but with High Sodium (Na)> 15% and ECe>4dS/m

A saline sodic soil, in addition to having poor water infiltration due to the sodium content, has a related problem of high salinity. The sodium problem contributes to the soil salinity since leaching of the soil salts out of the root zone is impeded by poor water movement within the soil profile.

Non-Saline Alkali Soil (Black Alkali) - pH from 8.5 to 10 with High Sodium (Na)>15% and ECe<4dS/m

Sodic soils characteristically have high levels of sodium which have a detrimental effect on soil structure. A sodic soil typically has poor water infiltration. Sometimes this soil is referred to as "black alkali" due to black soil crust common to this poorly drained soil.

Components of Saline, Alkaline, and Alkali Soils

The term saline soil generally refers to a soil that has a high concentration of salts. The two most common salts are sodium sulfate (Na_2S0_4) and sodium chloride (NaCl), with the other salts being composed of chlorides, sulfates, or bicarbonates of sodium: calcium, magnesium, and potassium. It should be noted that the predominate salt may vary from region to region.

The term alkaline generally refers to soils with a pH above 8.5. The term alkali generally indicates a problem involving high levels of Sodium (Na)>15%.

Origin of Soil Salts

Many soils trace the origin of their salts to the weathering of soil parent material that originated from deposits left by ancient inland seas. Other soils which are dominated by sodium chloride (NaCl), often trace the salt deposition to tiny concentrations from the ocean transported within clouds and deposited by rainfall over geologic time. Other sources can be attributed to the movement of salts by water such as rivers, irrigation water, and high water tables (saline seeps), and by fertilizers and soil amendments.

One of the most common sources of soil salts is irrigation water. Most if not all irrigation water contains some level of salt. It has been said that over time, irrigation leads to the salinization of soil and water and that all irrigated land will eventually have to be managed for salt. Irrigation water moves soluble salts containing sodium, calcium, magnesium, potassium, sulfate, and chloride from geological sources with which it has come in contact. It has been reported that the California aqueduct irrigation water deposits 700 pounds of salt for each acre foot of water applied. A full irrigation season using four acre feet of water, deposits 1.2 tons of salt per acre.

Across the Northern Great Plains and the Canadian provinces, saline seeps are often the source of soil salinity, when high water tables bring salts to the surface. Poor drainage practices, excessive irrigation or rainfall, and cropping practices such as crop-fallowing (alternate years) can contribute to high water tables that result in soil salt buildup from saline seeps.

Chemistry of Saline Soils and Water

Salts can be composed of negatively (anions) or positively (cations) charged ions of various minerals that are found in the soil and water. These differences in the type of electrical charge influence how the salts will interact with each other and with the various crops planted in the soils they comprise.

Irrigation water is a major source of salt applied to cropland. As streams and rivers flow across weathered parent material, soluble salts are absorbed and carried to the waters eventual destination.

Physical Properties of Saline Soils

All soils, including saline soils can vary as to pH, and depending on the region, can range from acid to alkaline. Studies have shown that an increase in soil salinity in itself has no affect in raising the soil pH. Crop species can vary in their tolerances to pH; however, pH tolerance is often independent of the tolerance to salinity. For example, a salt-tolerant alfalfa is not necessarily more tolerant to a highly alkaline soil with a pH of about 8.5. To successfully grow crops like alfalfa, extremes in pH outside the optimal pH range (6.5-7.5) are often modified with the use of soil amendments. Lime is often used for acid soils; for alkaline soils, sulfur, acid based fertilizers, and sometimes gypsum (which dissolves readily at high pHs) are often used.

Water Holding Capacity

Soil's ability to hold water is related to soil texture (sand-clay) as well as the soil structure. An increase in irrigation water salinity combined with increasing sodium levels can decrease the leaching efficiency of soils and negatively affect soil structure and its water holding capacity. As the soil solution becomes more saline, it affects the ability of plants to absorb water into their roots. An increase of the salts in the soil solution changes the strength of osmotic gradient of water into the roots. Plants must work harder and spend more energy by adjusting their internal cell solutions to make the osmotic gradient more favorable for water absorption.

Soil Structure/Salt Leaching

Another related factor to consider is the sodium absorption ratio (SAR) of the soil. The SAR is a ratio of soil extracts and irrigation waters used to express the relative activity of sodium ions in exchange reactions with soil. SAR values above 13 indicate that a soil has become high in sodium (Na), and as a result, will have poor soil structure and poor water infiltration or percolation. This in turn can lead to reduced water movement in the soil, and salts can accumulate due to the inability of rainfall and/or irrigation water to leach the salts from the root zone.

Irrigation water from the California Aqueduct deposits 700 pounds of salt with each acre foot of water applied.

Measuring Salinity

Measurements of salinity may vary depending on whether you are referring to the soil or water, and the unit of measurement may differ depending on who you ask. Plant physiologists often measure salt as an amount of electrical conductivity (EC) of the soil or water solution or use measures of water potential (bars or MPa). Water quality engineers measure salinity on a weight per volume basis, in milligrams per liter (mg/L) or parts per million (ppm). Chemists use a measurement of ionic (charged particle) concentration of particular salt in a solution in millimol (mM). The following table approximates the conversion between units.

CONVERSION CHART

Increasing Salinity ↓

Percent Salt (%)	Grams Per Liter (g/L)	Parts Per Million (ppm)	Mega pascals (MPa)	Bars	Electrical Conductivity dS/m*
0.125	1.250	1250	-0.07	-0.7	1.95
0.250	2.500	2500**	-0.14	-1.4	3.90
0.500	5.000	5000	-0.28	-2.80	7.80
0.750	7.500	7500	-0.42	-4.20	11.70
1.000	10.000	10000	-0.56	-5.60	15.60
1.250	12.500	12500	-0.70	-7.00	19.50
1.500	15.000	15000	-0.84	-8.4	23.40

*1 EC unit is equal to 1dS/m, 640 mg/L of Total Dissolved Salts.11 millimol of sodium chloride or 44 millimol sodium chloride.

** Each ECe point above ECe=2dS/m results in an approximate yield loss of 7.3% in alfalfa

*** Sea water is approximately 3% NaCl

Testing Soils for Salinity

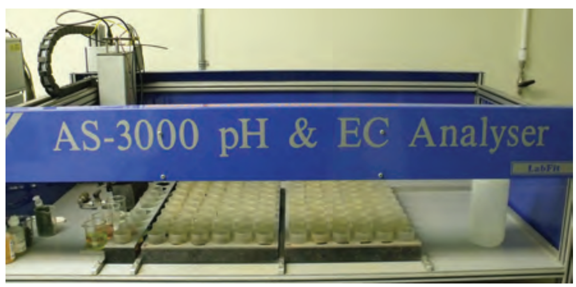
The first step in dealing with a potential problem is to determine what levels of salinity are present in the soil and/or irrigation water.

A plant's growth response in the presence of salts is related to level of total dissolved solids (TDS) in the soil solution. One of the most widely used methods of measuring soil and/or water salinity is using the electrical conductivity of the soil water solution (one EC is equal to 640mg/L of TDS). The electrical conductivity (EC) measurements are directly proportional to the salt concentration in the soil water, and the higher the salts, the higher the EC reading. The EC readings are generally expressed most often as decisiemens per meter (dS/m) or in older references as millimhos per centimeter (mmhos.cm). One dS/m is equal to 1 (mmhos/cm). Some references also use micromhos per centimeter (umhos/cm), which if multiplied by 1000 will equal 1 dS/m.

EC readings are often written with various subscripts to identify what type of sample was measured (i.e. ECw is from water, ECs is from the soil solution). One of the more common values is ECe which is derived from the saturated soil paste extract using deionized water following a standard lab method at 25˚ C and a calibrated EC meter reading approximately half of the estimated root zone salinity (ECsw). A common method of calculating EC soil values is by making a saturated water extract of a representative soil sample using a 1 to 1 ratio of the soil sample and distilled water. The EC reading of a 1-1 soil/water paste is expressed as EC 1-1(ds/m).

Crop Species with Salt Tolerance

For many years researchers have described salinity tolerance of crop species in terms of each crop's salinity threshold. The threshold being decribed as the point at which the soil salinity concentration begins to retard each crop's performance. Early such reports indicated that alfalfa's salinity threshold was at an ECe>2dS/m. It was thought that at this so-called tipping point, alfalfa started to show detrimental effects due to salinity. More recent research by Steppuhn, H., M. Th. van Genuchten, and C.M. Grieve in Crop Sci. 45:209-220 (2005) has indicated that the use of the term "threshold" may have been incorrect. The data tends to indicate that crop yield reductions were more continuous in nature than previously decribed and didn't necessarily start at a specific threshold point. The following chart approximates percent yield losses of many crop species at increasing ECe values.



Soil testing labs like Western Soil Testing Labs in Parma, Idaho, have specialized equipment to measure salinity and other soil components.

Estimated Percent Yield Reductions for Irrigated Crop Species with Increasing Salinity*

Crop Species	10%	25%	50%	100%***
Soil ECe Measurements**				
Alfalfa****	3.4	5.4	6.8	16.0
Barley	10.0	13.0	18.0	28.0
Bermuda Grass	8.5	11.0	15.0	23.0
Clover, Ladino	2.3	3.6	5.7	9.8
Clover, Red	2.3	3.6	5.7	9.8
Corn	2.5	3.8	5.9	10.0
Cotton	9.6	13.0	17.0	27.0
Fescue,Tall	5.5	7.8	12.0	20.0
Ryegrass, Per.	6.9	8.9	12.0	19.0
Sorghum	7.4	8.4	9.9	13.0
Soybean	5.5	6.3	7.5	10.0
Sudangrass	5.1	8.6	14.0	26.0
Wheat HRWW	7.4	9.5	13.0	20.0
Wheat, Durum	7.6	10.0	15.0	24.0
Wheatgrass, Cres.	6.0	9.8	16.0	28.0
Wheatgrass, Tall	9.9	13.0	19.0	31.0
Water ECw Measurements**				
Alfalfa****	2.2	3.6	5.9	10.0
Barley	6.7	8.7	12.0	19.0
Bermuda Grass	5.6	7.2	9.8	15.0
Clover, Ladino	1.6	2.4	3.8	6.6
Clover, Red	1.6	2.4	3.8	6.6
Corn	1.7	2.5	3.9	6.7
Cotton	6.4	8.4	12.0	18.0
Fescue,Tall	3.6	5.2	7.8	13.0
Ryegrass, Per.	4.6	5.9	8.1	13.0
Sorghum	5.0	5.6	6.7	8.7
Soybean	3.7	4.2	5.0	6.7
Sudangrass	3.4	5.7	9.6	17.0
Wheat HRWW	4.9	6.3	8.7	13.0
Wheat, Durum	5.0	6.9	10.0	16.0
Wheatgrass, Cres.	4.0	6.5	11.0	19.0
Wheatgrass, Tall	6.6	9.0	13.0	21.0

*Adapted from Ayers and Westcot, 1985, Water Quality for Agriculture, FAO, United Nations. This data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2 dS/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

** ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in deciSiemens per meter (dS/m) at 25°C. ECw means electrical conductivity of the irrigation water in deciSiemens per meter (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15–20 percent leaching fraction and a 40-30-20-10 percent water use pattern for the upper to lower quarters of the root zone.

*** The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

**** Conventional alfalfa varieties without improved salinity tolerance.

Salt Tolerance Classification of Plant Species: Halophytes and Glycophytes

A plant's ability to survive exposure to salt stress is dependent on its genetic ability to osmotically control internal and external salts as well as water movement from the soil solution into its root cells.

To control this process, plants have evolved using two basic methods: They can osmotically control salts by accumulating or storing excess salts in vacuoles within the cell cytoplasm to avoid injury, or they can internally produce organic acids and sugars of higher concentrations that help enhance their osmotic potential to facilitate water movement from the soil solution into the root cells.

Halophytes

The halophytes are the group of plant species that have evolved to survive in high saline environments. Halophytes do this by removing the effect of excess salts in cells by compartmentalizing excess salts within the cell cytoplasm into sacs called vacuoles, thus allowing the normal function of its cell contents.

Glycophytes

The glycophytes are more limited in their level of salt tolerance, but compose essentially all of our major crop species and therefore are the subject of most of the plant breeding efforts to improve salt tolerance. In general terms, the glycophytes try to cope with saline conditions by excluding or preventing the salts from entering cells by artificially increasing cell solutes. This improves the osmotic potential between the soil solution and the plant roots, allowing more water movement into the plant from the soil solution. However, this takes energy, and the end cost is a reduction in plant growth and yield. Alfalfa is a member of the glycophyte classification of plants and has moderate levels of salinity tolerance developed over centuries of natural field selection. This tolerance has enabled alfalfa to become a major crop around the world.

Salt Effects on Plant Growth Development

The affects of salinity on plant growth are for the most part related to the plant's inability to extract moisture and nutrients from a saline soil solution. Depending on the salinity concentration, these effects manifest as reduced plant growth, sometimes mimicking drought stress. As the salinity increases, plants expend additional energy trying to extract water and nutrients from the soil solution by making internal biochemical adjustments to improve their osmotic potential to cope with the salinity. This waste of energy by the plant is at the expense of growth and eventual crop yield.

Different species have varying levels of tolerance and thresholds at which growth begins to be retarded and less profitable. (See chart on Page 7 and below). These differences in tolerance have evolved over time and recently have been improved upon by plant breeders.

Soil Salinity Tolerance Indices for Selected Dryland Crops
(Higher Numerical Value = Higher Salinity Tolerance*)

Crop	Salinity Index*
AC Saltlander (Green Wheatgrass)	12.51
Tall Wheatgrass	11.73
Tall Fescue	8.63
Intermediate Wheatgrass	8.49
Barley	8.29
Improved Saline Tolerant Alfalfa	8.27†
Canola	8.00
Slender Wheatgrass	7.84
Alfalfa	6.79
Duram Wheat (Dryland)	5.20

†From unpublished data H. Steppuhn (2013) Ag Canada, Semiarid Prairie Agricultural Research Center, Swift Current, Saskatchewan

Germination and Seedling Effects

Plants are most sensitive to salt stress at germination and in the seedling stage. Some seeds will not germinate in high concentrations of salt, and if they do, the tender seed hypocotyls have to emerge through the soil surface which is often higher in salts due to surface evaporation. This surface soil can have salinity levels high enough to burn the young developing leaves, resulting in seedling death and poor stand establishment.

SALINE SOILS AND PLANT GROWTH

The germination and emergence of a newly-planted alfalfa field is the most critical step in its developing into a productive stand. Unless a salinity problem is identified in the soil or irrigation water prior to planting, seedling mortality (due to salt) often goes undetected by the producer until it exceeds 25%.

Mature Plants

As a general rule, mature plants or those having regrowth past the first harvest are more tolerant to higher concentrations of salt than they are at the seeding stage. Above-ground symptoms may be seen as reduced growth, yellowing, and in some cases leaf burn and/or top growth desiccation. Leaf burn is especially prevalent under sprinkler irrigation systems with poor quality water. Above-ground plant symptoms often mimic drought stress.

As salts in the soil solution increase, plants find it more and more difficult to absorb water and nutrients across the root cell membrane against this increasing osmotic gradient. Plant species have evolved over time with varying levels of tolerance. Those with tolerance are able to sustain growth at moderate levels of soil salinity. However, once a plant species' salt tolerance threshold is reached and surpassed, plant growth will begin to suffer. Once a critical salt concentration is reached, plant death will occur. In some cases soil moisture will actually be present, however, the plant is unable to absorb it.

The inability of the plant to absorb water from the soil due to salinity is similar to what a plant encounters during drought conditions. As in drought situations, the plant can't absorb sufficient water to sustain optimal growth. To some extent drought and salt stress appear to be somewhat interrelated, since salt-induced stress is compounded even more when plants are exposed to drought or water stress conditions. The plant growth symptoms are similar to what you would see under drought conditions.

Symptoms of salinity stress in established alfalfa usually appear after the plant's natural threshold has been crossed and often mimic drought or water-logged soil conditions.

Numerous soil and water management systems have been developed over the years to remediate or minimize salt buildup in fields and the resulting yield losses. These methods can be successful if applied on a long-term, consistent basis. Most management programs suggest the use of salt-tolerant plant species as one means of helping these saline-affected soils. However, in many cases the most salt tolerant plant species are not those that will provide an economic value to the grower. For this reason plant breeders have concentrated their efforts on improving important crop species such as alfalfa for salt tolerance.

Alfalfa is recognized as a crop species with moderate salt tolerance. This natural tolerance has evolved over the centuries as alfalfa moved from its Middle East origins to Europe, Africa, Asia and then to the New World. The chart (top of page 10) details alfalfa's natural salinity tolerance and establishes the baseline for improved salt tolerance in today's genetically improved varieties.

Saline Soils Effect on Alfalfa*

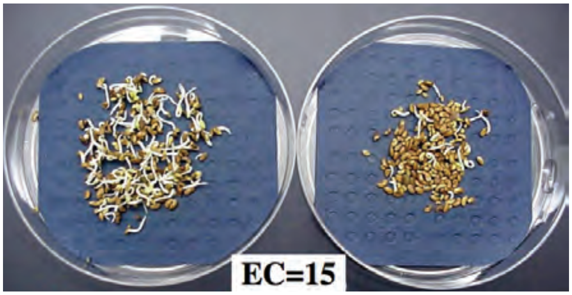
EC Range	During Germination/ Seedling Growth Stage	Mature Plant Stage
<1.0	No alfalfa limitations	No alfalfa limitations
1.0 - 2.0	5-10% seedling mortality	Negligible forage impact
2.0 - 4.0	10-35% seedling mortality	Forage losses up to 15%**
4.0 - 8.0	35-75% seedling mortality	Forage losses 35-75%
8.0 - 16.0	Consider another species	
>16.0		Alfalfa growth ceases

* Non-salinity improved varieties
** ECe>2dS/m is considered to be the economic threshold for non-salinity improved varieties.

Introduction

Alfalfa Breeding for Improved Salt Tolerance

When plant breeders first looked at breeding alfalfa for salt tolerance it became very apparent that it was a complex issue controlled by several genes. Johnson et al (1992) divided alfalfa into three stages in which it was affected by salinity: germination, seedling growth, and mature plant growth. Undoubtedly each of these growth stages is regulated by a different set of gene combinations. Based on this knowledge, a multi-tiered approach was decided on for genetic improvement. The first stage was selection for the ability to germinate under salt stress, and germination tolerance to salt stress was found to be heritable. The first salt tolerant alfalfa varieties to reach the market were those with improved germination followed by those with improved forage production, and most recently, varieties possessing both genetic improvements.



Germinating alfalfa seeds in the laboratory with high EC water can quickly screen and identify populations with different salt tolerance levels.

Protocols for Claiming Salt Tolerance

Alfalfa varieties with anecdotal claims of salt tolerance have been around for some time. Recently alfalfa breeders have developed a scientific system to validate and standardize the salt tolerance evaluation process for new commercial alfalfa varieties. The North American Alfalfa Improvement Conference (NAAIC) has developed two standardized tests for salt tolerance: (1) germination salt tolerance and (2) forage production under salt stress.

These tests have standardized protocols for all breeders to follow to verify claims of salt tolerance in commercial alfalfa varieties. The standardized test data for commercial varieties may be submitted and approved by the National Alfalfa and Miscellaneous Legumes Board.

Salt Tolerance Defined

Commercial varieties with improved salt tolerance are identified as having germination salt tolerance, forage production under salt stress, or having both traits. The traits are defined as follows:

Germination Salt Tolerance

Salt Tolerance for germinating seeds of this variety is similar to the tolerant check variety used in the North American Alfalfa Improvement Conference (NAAIC) Standard Test. The variety may or may not have been reviewed and approved by the National Alfalfa and Miscellaneous Legumes Board. http://www.naaic.org/resource/stdtest.php

Forage Production

Forage production of this variety under saline stress is similar to the tolerant check variety used in the NAAIC Standard Test. The variety may or may not have been reviewed and approved by the National Alfalfa and Miscellaneous Legumes Board.

Germination and Forage Production

Salt tolerance of germinating seeds and forage production under saline stress is similar to the tolerant check varieties used per the NAAIC Standard Tests. The variety may or may not have been reviewed and approved by the National Alfalfa and Miscellaneous Legumes Board.

USE OF SALINITY TOLERANT VARIETIES

To identify parent plants with improved genetic tolerance, plants are irrigated with water containing high concentrations of salt until all but the most tolerant have died. Surviving plants are then grown-out and crossed with other survivors. The process is then repeated with the progeny. After multiple cycles the best progenies are combined to form new varieties.

Commercially Available Salt Tolerant Varieties

The first alfalfa varieties approved by the National Alfalfa Variety Review Board for salinity tolerance were released in the late 1970s and early 1980s and were non-dormant varieties adapted for the southwestern United States. Since then several varieties have been released for both dormant and non-dormant alfalfa growing regions.

Salinity Breeding Progress*

It is generally thought that today's alfalfa varieties with improved germination salt tolerance reduce the impact of salinity on seedling mortality by 2-3 EC Points*. For a field with EC measurements approaching EC 4 seedling mortality could be reduced from 35% to a negligible percentage. At ECs above 8, the benefit is greatly reduced.

For varieties with improved salinity tolerance for forage production, saline soil yield loss can be reduced by 7-8% per EC point until the variety's threshold is reached.

A variety with both germination salt tolerance and forage production is recommended for soils with ECs exceeding 2.

On-Farm Performance

Varieties with improved salinity tolerance for germination and/or forage production are making a difference for growers with salinity issues. These varieties are pushing acceptable yields further into the hot spots, negating the effects of low-level germination and yield losses, and enabling growers to better utilize available irrigation water.

Private and Public Testing

Salinity levels are not uniformly distributed across a field or within the soil profile as verified by research published by Ag Canada at the Swift Current, Saskatchewan Semiarid Prairie Agricultural Research Center (Steppuhn 2012). Consequently, head-to-head replicated yield trials are difficult to manage and have rarely given clear results, and therefore are seldom undertaken by public and private researchers.

Misconceptions About Salinity-Tolerant Alfalfa

A common misconception about the use of salt tolerant varieties is that they are only for saline soils and won't be competitive on non-saline soils. Salt tolerant varieties were developed from top performing varieties, and a yield drag has not been seen on non-saline soils where the variety is adapted. They are usually the top performing varieties on the farm.

Advanced Breeding Techniques

Plant breeders in recent years have begun to realize that conventional plant breeding for salt tolerance has its limits, and in order to expand salt tolerance, other measures will be needed. The use of advanced breeding techniques may provide the next great advancements in salt tolerance. Advances are being made in identifying genes associated with salt tolerance and will eventually improve through the use of marker assisted selection. This new generation of plant selection will help plant breeders increase their selection efficiency and help them find that needle in the haystack of genetic salt tolerance. This new generation of varieties has the potential of taking alfalfa salt tolerance to a whole new level.

*Actual performance may vary due to environmental conditions and other management practices.

Managing Irrigated Alfalfa with Low to High Salt Levels

For alfalfa growers in arid areas the first step in dealing with saline problems or potential salinity issues is to determine what levels of salinity are present in the soil and available irrigation water. The use of a portable hand held EC Meter can detect whether or not a field's salinity level is below, above, or at crop threshold levels. Those readings can be used to estimate base line yield losses.

If a serious problem is detected, a more complete sampling and soil lab analysis may be warranted to identify all other salinity related issues as well as determine the long-term management decisions for the grower.

Handheld portable EC Meters can help monitor salinity levels and provide valuable management information to growers.

Interpreting Soil Tests

Interpreting soil reports can be a complicated issue due to the numerous interrelationships of the soil components. Therefore it is recommended that your soil lab or crop consultant be consulted for specific recommendations. A few of the important factors to be considered as related to salinity and alfalfa production are:

pH

Alfalfa's optimal range is 6.5-7.5 - pH values for other crops will vary depending on the crop species. In the case of alfalfa, values below 6 and above 8.4 will require some form of soil amendment or corrective measure in order to maximize yields.

Sodium Absorption Ratio (SAR)

A SAR value below 13 is desirable. SAR values above 13 will adversely affect soil structure and water infiltration, which in turn can hinder salt leaching from the root zone.

Soluble Solids

Salinity in a soil test report is generally described as soluble solids and expressed as an ECe value. ECe values below 2dS/m indicate reduced salinity and are desirable for optimal crop production. Crop tolerance to salinity can vary by crop species (see table Page 7). Selection of varieties with EC tolerance levels appropriate for soil ECe salinity levels should be used to minimze yield losses.

Alfalfa varieties from fall dormancy 3 to 10 with improved germination and/or forage production salinity tolerance are available for all production zones found in western North America. These varieties compete toe-to-toe with the best conventional varieties for yield and multiple-pest resistance when salinity concerns aren't present.

Salinity occurs wherever irrigation is used, since almost all irrigation water contains some level of dissolved salts. First crop alfalfa near Dillion, Montana, May 2013

Optimal Soil Test Ranges

pH ....6.5-7.5 (alfalfa)	Manganese ppm 6.0-30	Soluble Salts ....<1.5	Iron ppm .... 25+
% lime .... 0.5-1.5% lime	Boron ppm 0.7-1.5	Nitrates ppm 10.0-35	Ammonium ppm .... 5+
Phosphorus ppm 25-40	Phos-ppm-Bray 50-100	Potassium ppm .... 300+	Potassium Bicarb ppm .... 250+
Sulfate ppm .... 20+	Calcium ppm .... 1800+	Magnesium ppm .... 250+	Sodium ppm .... <225
Zinc ppm 1.0-3.0	Copper ppm 0.8-2.5		

CEC % Base Saturation

Calcium % of CEC 65-80	Magnesium % of CEC 10.0-20	Potassium % of CEC 2.0-6.0	Sodium % of CEC (ESP) ... <5
Hydrogen % of CEC .... <15	Ca:Mg Ratio 6-20:1	CaP pH >7 .... 100 to 1	CaP pH <7 .... 40 to 1
P-Zn .... 15 to 1			

Information from Western Laboratories, Parma, Idaho

Soil EC Effect to Alfalfa

EC Range	Crop Effect to Unimproved Varieties for Germination or Forage Production Salinity Tolerance
<1.0	No limitations
1.0 - 2.0	5-10% seedling mortality and negligible forage yield impact
2.0 - 4.0	10-35% seedling mortality or forage losses up to 15% in established fields
4.0 - 8.0	35-75% seedling mortality and significant forage losses from 35-75%. Alfalfa varieties with improved salinity tolerance should be used to minimize yield losses.
8.0 -16.0	Should consider other salt tolerant species
>16.0	Alfallfa growth ceases

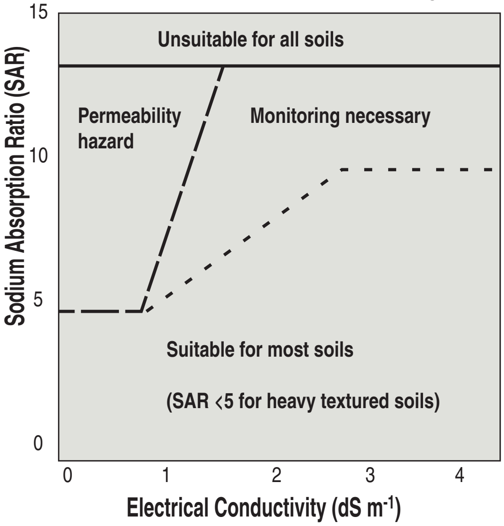
Water EC Effect to Alfalfa

EC Range	Crop Effect to Unimproved Varieties for Germination or Forage Production SalinityTolerance
<1.3	No limitations
1.3 - 2.2	Neglible yield reductions
2.2 - 3.6	15-35% yield losses possible
4.0 - 5.9	35-75% yield losses possible
5.9 - 10.0	Should consider other salt tolerant species
>10.0	Alfalfa growth ceases

Water Evaluation for Salinity

Knowledge of the quality of the water used for irrigation is very important in managing salinity. The level of the various salts will determine what crops can be grown and what long term irrigation strategies must be used to keep the farm land from becoming unproductive due to salts. This information can also help predict the compounding issue of sodium buildup (SAR) and the resulting loss of soil permeability due to poor soil structure.

Guideline For Use of Sodic Waters For Irrigation



*Steppuhn + Curtin 1993 Ag Canada, Swift Current, Saskatchewan

Irrigation water having total dissolved solids (TDS) of less than 300mg/L or EC 0.5dS/m is classified as good water. Poor quality water has TDS values greater than 300-800mg/L or ECs 0.5dS/m to 1.2dS/m.

When ECs are used to measure irrigation water the following criteria is used. ECw designates the electrical conductivity (EC) of the irrigation water in decisiemens per meter (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15-20% leaching fraction and a 40-30-20-10% water use pattern for the upper to lower quarters of the root zone. (i.e. 40% of water use is in the top 25% of root zone).

What do I do if my soil and/or irrigation water analysis indicates elevated salinity levels?

Once a salinity problem is identified either in the soil and/or the irrigation water, several options are available to the producer. Depending on the severity of the problem, a combination of improved genetics, soil amendments, and/or salt management practices can be implemented to limit further salt buildup and minimize potential yield losses. The following are a few of the management practices currently available to producers in various geographies that can help reduce or limit salinity related crop production losses.

Pre-Plant and Planting Time Considerations

Alfalfa growers who produce commercial hay or home-grown feed for their livestock have a number of factors to consider as they choose fields to rotate into alfalfa. Two primary factors are pH and fertility.

pH

For alfalfa, the optimal pH is 6.5-7.5. It should be noted that new salt tolerant alfalfa varieties have been bred for tolerance to salinity, not extremes in pH. Alfalfa production in acid soils (pH<6) or alkaline (pH>8.4) is generally difficult. In those cases soil amendments to modify the pH would be advised. Gypsum helps reclaim sodic soils and saline sodic soils because it still adds calcium when applied to high pH soils. Elemental sulfur lowers the pH and frees up calcium.

Fertility

Good soil fertility to promote plant health is advisable. However improved fertility in itself will not provide increased tolerance to salinity. The main point to consider is whether or not some nutrients are out of balance or unavailable due to soil chemistry interactions. In some cases the available soil nutrients as measured by CEC (Cation Exchange Capacity) may be affected by sodium build up and the available lime. Also in some situations specific ions can build up in toxic levels (i.e. boron). A soil test can identify these problems and suggest possible remedies.

Alfalfa Seed Selection

Variety selection should be first based on fall dormancy and the winter survival rating to insure adaptation for where it is going to be grown. Then other desirable characteristics such as salinity tolerance can be considered.

Irrigated alfalfa in arid areas doesn't automatically mean a salinity tolerant variety is needed. Use a current soil test to assess which fields need a salinity variety and the type of tolerance needed.

Use the National Alfalfa and Forage Alliance (NAFA) website at http://www.alfalfa.org to see the latest winter survival, fall dormancy and pest resistance ratings for alfalfa varieties. It has a listing of commercially available alfalfa varieties that have been bred for improved germination and/or forage production under salinity stress, salinity tolerance, and other variety characteristics needed to maximize the economic returns for each field.

Inoculants, Treatments, and Seed Coatings

Alfalfa seed is generally sold pre-inoculated with rhizobium that promotes efficient symbiotic nitrogen production in the field. Today's inoculants are usually a mixture of strains that work in a wide range of soils including salinity. Several fungicides are compatible with rhizobium and provide germination and seedling protection to alfalfa with or without salinity concerns.

Seed coatings are widely used today to carry innoculants and seed treatments to enhance seedling survival which may be especially helpful for fields with elevated salinity.

Seeding Rates

For irrigated production, 18-25 pounds acre is the normal recommendation. Under saline soil conditions it is often advisable to increase the planting rate if using a variety that does not have improved germination salt tolerance. Soil salinity may directly reduce seedling survival, and a higher initial number of seeds may facilitate a more adequate stand. Selection of an alfalfa variety bred for increased germination salt tolerance is also advisable if stand establishment is difficult or if poor quality irrigation water is available at planting. In some regions soil crusting increases with salinity and a higher seeding rate may facilitate more seedlings in breaking through the crust. In most situations growers should plant on the high end of the normal planting rate or slightly higher in more severe saline conditions.

On fields with elevated salinity, alkalinity or where crusting may be a problem, use higher seeding rates to assure an adequate stand.

Seed Mixtures

When planting in marginal and/or variable soil conditions it is sometimes advisable to plant a seed mixture of two or more species. In variable soils one species may not be adapted to establish well in all parts of the field. An optimal species mix can buffer against variable stand establishment. In these situations each species may compensate the other's lack of production across the field.

Best Planting Time

Depending on the region, several planting date options exist. In warmer and more arid climates, planting should be avoided in hot periods when crusting may occur. Salts tend to accumulate at the soil surface due to evaporation. In these cases fall planting may be preferred when adequate moisture is available. In some regions the best quality water is available early in the season, which may affect the planting decision.

Seed Placement

Depending on the severity of the soil salts and type of irrigation system, some growers have learned that seed placement may minimize the salt exposure of the young tender seedling to salt. The front edge of water movement is called the leaching front and is generally high in salts. The goal of proper seed placement is to manage water movement of salts in the seed bed to minimize the salts in the soil next to the seed at the time of germination. Some methods include planting in the furrow versus the top of the bed where salts may accumulate at the peak. Growers may also plant on the side of domed beds to avoid salts that migrate to the top of the bed. The practice of irrigating alternating furrows to push salts to the opposite side of the furrow out of the root zone can also be effective. In drip irrigation systems the wetting zone edge where salts accumulate is kept outside the plant growth zone to minimize the salt exposure.

Irrigation Management

Factors to consider regarding irrigation practices and how they relate to salinity.

Flood Irrigation

Flood irrigation is preferred over sprinkler irrigation if salt is a problem. The larger amount of water applied during flood irrigation generally promotes more leaching of soil salts from the root zone. Some irrigated farms have access to multiple sources of irrigation water during the growing season, and in some cases the water quality will vary with the source. Good quality irrigation water has less than 300 mg/L of TDS or an EC 0.5 dS/m. Poor quality irrigation water has TDS values greater than 300-800 mg/L or ECs of 0.5 dS/m to 1.2 dS/m. Seedlings are more susceptible to salinity, so utilization of the best water for the pre-plant and the first irrigation can increase stand establishment. Poorer quality water can be used on established stands, later in the season, or on more salt tolerant species. Some regions blend their good and poor irrigation water together as a means of utilizing more of their available irrigation water supply.

Irrigated farms using row or flood irrigation generally first see salt problems at the bottom of the field furthest from irrigation source. To minimize the effect of the water that accumulates at the low end of the field (tail water) that is high in salts, surplus water should be drained off and/or reused if possible on more saline tolerant crops.

Flood irrigation using canals, ditches, and siphon tubes has been a practical irrigation method since ancient times and is still used in many key alfalfa production regions today.

Sprinkler Irrigation

In recent years there has been less and less water available for crop production, and as a result farmers have installed sprinkler systems to conserve water. These systems provide the producer with more efficient water control and use less water compared to flood irrigation. However leaf burn may be more prevalent using sprinklers, especially if the water is high in salts. Nighttime watering may be beneficial in these cases since salt leaf burn is more prevalent in intense heat and sunlight. Sprinkler irrigation applies less total seasonal water than flood irrigation, and as a result it provides less leaching of the soil salts from the root zone. In these systems monitoring at various depths in the soil profile is critical. If soil salts are nearing high levels in the root zone it may be advisable to periodically leach salts from the root zone with a heavy irrigation.

Center pivots are an efficient way to irrigate large acreages of alfalfa. This efficient use of available water and saline water requires regular monitoring to manage potential salinity induced yield losses.

Wheel lines are a practical way to irrigate acreages or difficult terrain. Like the center pivots, they require regular monitoring to minimize potential salinity concerns.

Drip Irrigation

To conserve water, drip irrigation systems are also being used in alfalfa production. One limitation, however, of drip irrigation systems is that deep soil leaching of salts out of the root zone doesn't occur. Drip irrigation systems can tolerate higher levels of salinity in the water since a constant wet zone can be maintained around the plant, in which the salts are pushed to the edge of wetting zone away from the plant roots.

This exposed drip irrigation lateral demonstrates how the constant wet zone delivers water to the plant and keeps salts confined to the edge of the wet zone. This is a popular irrigation system when high value crops are grown in rotation with alfalfa.

Managing Dryland Alfalfa with Low to High Salt Levels and Needing Remediation

Lower rainfall areas inherently have more salt problems due to their lack of adequate water to leach salts from the soil root zone. Higher rainfall areas have the benefit of rainwater that is absent of salts and therefore doesn't contribute additional salts to the soil. Dryland salinity on farms and pastures is generally the result of two basic processes, (1) surface soil evaporation and (2) saline seeps from high water tables.

In hot arid regions the top two or three inches of the soil profile often accumulate salts, a result of surface soil evaporation without adequate soil leaching. In the absence of sufficient rainfall and/or irrigation to leach the salts out of the root zone, salts will remain near the surface.

In other regions, surface salts are the result of high water tables that bring dissolved salts to the surface in the form of saline seeps. The increase in saline seeps on agricultural land is attributed to the removal of native perennial vegetation by cropping and/or overgrazing. Before modern agriculture, many dryland areas had adequate ground cover that reduced surface evaporation and salt buildup near the surface. The practice of crop fallowing in dryland regions as a means of maximizing soil moisture has compounded this issue and increased the size and number of saline seeps.

Rainfall and Yield Expectations

Dryland alfalfa grown in dormant alfalfa growing areas usually needs a minimum of 13-24 inches of annual moisture to be productive. The amount of rainfall and its timing influences the yield expectations that can be achieved from planting a salt tolerant variety. At planting time, rainfall can make or break stand establishment in dryland areas and dilute salts at the soil surface. Annual rainfall will determine seasonal yields. In production years with low precipitation, the number of cuts per season should be limited to minimize plant stress. Excess harvesting can deplete the plant's root reserves, reduce stands, and increase soil salinity.

Pre-Plant and Planting Time Considerations

Many pre-plant activities such as soil testing, correcting pH, or fertility deficiencies with soil amendments, and selecting an adapted seed variety are the same for both irrigated and dryland crop production.

Seeding Rates

In dryland production areas seeding rates and stand densities are lower than in irrigated areas. Dryland planting rates are generally in the 9-12 pounds per acre range. However, in the presence of salinity the higher rate may be advisable if a saline tolerant variety isn't available. In some cases the higher seeding rate provides more plants to break through crusting that may occur.

Seed Mixtures

When planting in marginal and variable soil conditions it is sometimes advisable to plant a seed mixture of two or more species. The mixture will buffer the effect of the variable field conditions, where each may perform better than the other.

Best Planting Time

Planting in dryland areas is normally done in the spring or fall, and timed with moisture availability. Soil crusting is usually a problem with summer seedings.

The use of a no-till drill can help with seed placement and soil-to-seed contact to improve total germination and seedling survival on tough, dryland soils.

Harvest Timing and Grazing

In dryland regions, harvesting and grazing frequency should be a management decision based on the amount of forage available to harvest and the drought and salt stress imposed on the plants during a given season. Lower rainfall years tend to increase plant stress and deplete root reserves. Drought increases soil salts which limit the ability of the plant to extract water from the soil. In higher rainfall years, when the plant is actively growing, more harvests and or grazing is possible. In dryer years it may be only advisable to take the spring cut and limit subsequent cuts to later in the year. Overall plant health, as it is affected going into the winter, should be taken into account as late summer and fall harvest and/or grazing is considered.

Salt Management for Saline Seeps in Northern Regions

Salinity problems in the colder prairie regions of Montana, the Dakotas, and Canadian provinces are often the result of the salt accumulation in poorly-drained low-lying areas of fields.
In some cases the salinity problem is the result of rising watertables which bring soil salts to the surface in what are called saline seeps. Farmers have dealt with these saline soils for years mainly by farming around these areas. In recent years, no till farming, fallowing, and periodic above-normal rainfall has resulted in an increase in the size of these saline seeps. Based on recent research, many production areas that are prone to saline seeps are utilizing a two- species approach by using salt tolerant alfalfa varieties in conjunction with a

AC Saltlander in a grazing trial had average weight gains of 2.3 pounds per day versus 2.2 pounds per day from bromegrass.

new salt tolerant grass called AC Saltlander. The alfalfa with its deep taproot is used to interrupt and reduce the water flow in saline seeps from the water table recharge areas. The farming operations are then utilizing AC Saltlander's higher salt tolerance in the low lying areas of the saline seeps where higher levels of salt tolerance are needed. This integrated species approach, combined with other management techniques, has proven to be effective.

Planting in Saline Seep Areas

Often it is difficult to get equipment on these saline seep soils during the growing season to plant new salt tolerant species. One method that avoids this problem is dormant or frost seeding which occurs after the soils are frozen. Dormant plantings utilize spring soil moisture better than late spring plantings.

Weed seed banks in the top two inches of the soil profile need to be dealt with (particularly foxtail barley) or the weeds may overwhelm the new seedlings in the spring. Disking to a depth of 4-5 inches before freeze-up, followed by a leveling packing operation, is usually successful.

Saline seeps are all too common a site across the Northern Plains and Canadian Prairies. Just in the state of Montana it is estimated 300,000 cropland acres have been lost to salinity.

Clay and loam soils are best suited for frost seeding. During the course of the winter, the freezing and thawing action in these soil types creates cracks in the soil which allows the seed to work its way into the soil, facilitating germination in the spring. Sandy soils are less favorable for frost seedings due to desiccation.

Planting rates should be increased when frost seeding. Planting should occur in November or later. Planting must occur when air and soil temperatures are cold enough to prevent seed germination. Cool season grasses can germinate at 40°F, so it is recommended that soil temps should be 35°F or less for at least a week before planting.

Conventional and no-till drills, air flow seeders, and broadcast spreaders have all been successfully used for dormant plantings. Any excessive plant material from previous crops should be mowed or grazed down to a level 2 inches or tilled to allow optimal seed placement. Broadcast seedings can occur on top of snow (< 5 inches) as long as the seed bed under the snow will still allow adequate seed-to-soil contact once the snow melts in the spring. Some producers have successfully used livestock trampling to incorporate broadcast seedings. If this method is used to incorporate the seed, livestock should be removed in the spring once germination has occurred.

Sodium sulfate, magnesium sulfate, calcium sulfate, and sodium chloride are the most common soluble salts found in saline soils across North America. Sulfate based salts are more often associated with saline seeps.

Salt Management Considerations for High and Low Desert Regions

The basic strategy for the management of saline soils in the southwestern United States and Mexico is usually centered first on the amount of available water and its quality, second on the ability to remove salts from the root zone by leaching or improved drainage, and last by the addition of soil amendments. The following are a few of the practices used to accomplish those objectives:

Irrigation

In preparation for planting, pre-irrigate with enough water to leach soil salts from the germination zone or anticipated seedling root zone.

Crop Species

Select a plant species that is tolerant or unaffected by the salinity level present in the soil. Alfalfa varieties with improved germination salt tolerance and/or forage production on saline soils can improve stand establisment and reduce yield losses.

Seed Placement Strategies

Seed bed and seed placement strategies can be used to minimize seedling mortality at establishment. As water moves through the soil it carries salt with it. Where the movement stops is where the salts accumulate. Most planting strategies involve avoiding where the wetting front of the water deposits the soil salts and placing seed in the salt free zone. Placing seed at the bottom of a furrow verses on top is another way to execute this strategy.

Water Quality and Irrigation

Most producers in the southwestern United States have 4 to 5 acre feet of water available annually. This necessitates that all available surface and well water be utilized during the growing season. Strategies include using the best quality water on germinating and seedling crops and using lower quality water on less salinity sensitive crops. Sprinkler irrigation tends to increase root zone salt concentrations versus flood due to less leaching. However, periodic heavy watering can be used to leach salts down in the root zone or out of the root zone. Drip irrigation promotes higher yields by pushing the soil salts to the front edge of the wetting front in the soil profile outside of a root zone.

Remediation of Saline Soils

First and foremost the reclamation of saline soils requires adequate drainage to leach salts from the plow layer and crop root zone. The following are a few of the more common remediation practices used today:

Crop Rotation and Crop Selection

The decision of what crops to use on saline affected soils is dependent upon the salinity of the soil. Crop species have varying levels of genetic tolerance to salinity and as a result differ in their ability to remain productive as soil salinity increases. When starting to reclaim saline soils, select a crop that will tolerate the level of salinity in the field, and over time, with integrated soil and water management practices move to less salt tolerant crops that have more economic value. In severe situations, establishing a perennial grass may be the best long term option in stabilizing a marginal soil until other management options are available.

Managing soil and water salinity in low desert environments is especially challenging for growers. The long growing seasons, high temperatures, and limited availability of quality water can accelerate salinization if regular remediation practices are not followed.

Salt Tolerant Alfalfas

The development of salt tolerant alfalfa varieties has given forage producers another means to combat salinity. When combined with sound soil and water management practices, growers have an integrated approach to maximizing forage yield and economic return per acre.

Soil Amendments

The utilization of soil amendments to improve saline soils is, for the most part, an indirect method. Soil amendments only aid in helping improve the soil structure in a manner in which the soil salts can be leached out of the soil profile.

The addition of soil additives such as lime or gypsum can improve the soil structure which facilitates the leaching of the salts out of the soil profile. Depending on the soil pH, two basic methods are generally used. Gypsum helps reclaim “sodic soils” and “saline sodic soils” because it still adds calcium when applied to high pH soils. Another method to correct the sodium problem is the use of elemental sulfur which lowers the pH as a means of freeing up calcium (lime must be available in soil). Adding organic matter to the soil can improve soil structure and aid in leaching the salts. However, it must be noted that manure does contain some level of salt and excessive applications of manure may increase the salinity load in the soil.

A high producing dairy cow can produce up to four pounds of salt per day in its manure or nearly 1,400 pounds annually to be applied as manure to cropland.

Government Cost Sharing

Recent U.S. Farm Bills have several incentive programs to encourage the stabilization of marginal soils using perennial forages and/or improved water management. Two widely used programs are the Conservation Reserve Program (CRP) and the Environmental Quality Incentive Program (EQIP). Both programs have components that can be utilized to help stabilize and/or reclaim saline soils.

In addition to federal programs, numerous state and local organizations exist such as soil conservation districts that can provide expertise and assistance in managing saline soils. One prime example is the Montana Salinity Control Association (MSCA), a satellite organization of Montana’s Conservation Districts. MSCA provides producers with technical assistance in the reclamation and control of saline seeps in agricultural areas. Their program highlights the use of perennial deep-rooted forages such as alfalfa in non-saline recharge areas and the use of salt-tolerant forages in saline areas to control/reclaim cropland losses due to saline seeps. Saline tolerant forage is planted closer to the saline seep when the conditions are favorable, which may be at the same time as the alfalfa but often delayed until saline conditions improve as the water table is lowered.

Improved non-dormant alfalfa varieties with salinity tolerance offer alfalfa growers in the southwestern U.S. and Mexico added yield potential.

FOR MORE INFORMATION

Summary

The battle against soil salinity started when ancient civilizations began to irrigate their crops and has continued century after century to this day. It is only in recent years that agriculture, with the help of science and new technologies, has discovered that salinity doesn't have to be the end result of long-term irrigation. Unlike ancient civilizations, today's forage producers (irrigated or dryland) have at their disposal tools to slow down and remediate salinity. The world's rapidly growing population and disappearing crop land make controlling salinity a worldwide priority.

Along with soil remediation and sound soil and water management, improved salt tolerant alfalfa varieties offer new tools for the arid production regions of the world. These improved varieties raise the salinity threshold over unimproved varieties to maximize seasonal forage yield.

Peer Reviewed

- Jane Holzer, Montana Salinity Control Association (MSCA)
- Dr. Mike Peele, USDA-ARS, Utah State University
- Dr. Steve Smith, University of Arizona
- Dr. Harold Steppuhn, Ag Canada, Swift Current, Saskatchewan, Semiarid Prairie Agricultural Research Center

Ask the Expert

For questions about salinity, salinity management or alfalfa variety recommendations, e-mail AskTheExpert@alforexseeds.com. Please include name, city, state and contact information along with your specific question.

The approximately 9.5 million acres of alfalfa in the 17 Western States is a major contributor to efficient milk and beef production. As competition for land and water continue to escalate, alfalfa varieties with genetically improved salinity tolerance will become even more imporant to Western forage producers.

The information contained in this guide is based upon information currently available to Alforex Seeds for the purpose of advancing knowledge relating to salinity in soil and it is not intended to be the sole information resource for decision-making relating to alfalfa production.

FOR MORE INFORMATION

References

Ayers, R.S. and D.W. Westcot. 1976. Water Quality for Agriculture. FAO Irrigation and Drainage Paper No, 29 (Rev 1). Food and Agriculture Organization of the United Nations

Brown, P.L., A.D. Halvorson, F.H. Siddoway, H.F. Mayland, and M.R. Miller. 1982 Saline-Seep Diagnosis, Control, and Reclamation. U.S. Department of Agriculture Conservation Report No.30

California Agriculture: Salinity in California. October 1984; vol. 38, number 10

Franzen, D., March 2007. Managing Saline Soils in North Dakota, SF-1087. North Dakota State University.

Hanson, B., S.R. Grattan and A. Fulton. 1999. "Agricultural Salinity and Drainage." University of California Irrigation Program. University of California, Davis.

Holzer, J.M., S. K. Brown, R. G. Legare and J. J. Von Stein. 1998 Solving Saline Seeps Using Perennial Forage Rotations. 1998 North American Alfalfa Improvement Conference Bozeman, MT

Horneck, D., J.W. Ellsworth, B.G. Hopkins, D.M. Sullivan, and R.G. Stevens, November 2007. Managing Salt-Affected Soils for Crop Production. A Pacific Northwest Extension Publication PNW 601-E

Johnson, D.W., S.E. Smith and A.K. Dobrenz. 1992 Genetic and phenotypic relationships in response to NaCl at different developmental stages in alfalfa. Theoretical and Applied Genetics (1992) 83:833-838.

Maas, E.V. 1984 Salt Tolerance of Plants. In Handbook of Plant Science in Agriculture

Maas, E.V. 1977 Crop Salt Tolerance., J. Irrig. And Drainage Div. ASCE 103(IR2):115-134

Pessarakli, M., 1999 Handbook of Plant and Crop Stress, Second edition, 1999:1-15

Maas, E.V. and G.J. Hoffman, 1977. Crop salt tolerance - current assessment. J. Irrig. Drainage Div. Am/ Soc. Civ. Eng. 103:115-134

Rhoades, J., and J. Loveday 1990 USDA-ARS U.S. Salinity Laboratory. Salinity in Irrigated Agriculture

Rhoades, J., 1990 USDA-ARS U.S. Salinity Laboratory. Management of Saline/Sodic Soils

Richards, L.A (ed.).1954. Saline and Alkali Soils: Diagnosis and Improvement . USDA-ARS Agricultural handbook No. 60

Scianna, J., 2002 Salt-Affected Soils: Their Causes, Measure, and Classification. Hort Note No. 5. Plant Materials Center-NRCS, Bridger, MT

Smith, S.E., 1993. Salinity and the Production of Alfalfa (Medicogo sativa L.) p 431-448 In M Pessrarkli (ed) Handbook of Crop Stress

Steppuhn, H., M. Th van Genuchten, and C.M. Grieve. 2005 Root Zone Salinity: II. Indices for Tolerance in Agricultural Crops. Crop Sci. 45:221-232

Szabolcs, I., 1985. Salt affected soils a World Problem. p 30-47. In The reclamation of salt-affected soils. Proc. Int. Symp. Jinan China

Tober, D., W. Duckwitz and S. Sieler. 2007. Plant Materials for Salt-Affected Sites in the Northern Great Plains. NRCS USDA

USDA, Natural Resources Conservation Service. 2002. Soil Conservationists. Salinity Management Guide - Salt Management. Available at http://www.launionsweb.org/salinity.htm. 2002.

Warrence, N.J., J.W. Bauder, and K.E. Pearson. 2002 Basics of Salinity and Sodicity Effects on Soil Physical Properties. Land Sources and Eniv. Sci. Dept., Montana State Univ.

Alfalfa & Forage Excellence

18369 County Road 96
Woodland, CA 95695
800-824-8585
www.alforexseeds.com