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Plant species on salt-affected soil at Cheyenne Bottoms, Kansas

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Soil salinity and vegetative cover were investigated at Cheyenne Bottoms Preserve, Kansas in an effort to identify and document the plant species present on naturally occurring salt- and sodium-affected soil. Soil salinity (as indicated by electrical conductivity, EC_e) and sodium adsorption ratio (SAR) were measured from nine soil samples collected to a depth of 20 cm in June 1998. Vegetative cover was visually estimated in June and September 1998. A total of 20 plant species were encountered at five soil sampling locations on soils classified as saline, saline-sodic, or sodic. Dominant species observed include *Agropyron smithii*, *Distichlis spicata, Euphorbia geyeri, Poa arida*, and *Sporobolus airoides*. While most species encountered during this study exhibited greater vegetative cover on non-saline soils, all of the dominant species, except *A. smithii*, exhibited greater cover on salt-affected soil compared to non-saline soil. Comparable salinity levels and species found in areas that have been degraded through oil and gas production activities suggest that the dominant species observed in this study deserve further attention as potential candidates for the restoration of salt-affected areas.

Key Words: brine contamination, Cheyenne Bottoms, restoration, saline-sodic, salinity, salt tolerance.

INTRODUCTION

Salt-affected soils are commonly found in arid landscapes where evapotranspiration exceeds precipitation throughout most of the year (Jurinak 1990). In the United States, salt-affected soils cover about 16 million ha, while a total of approximately 322 million ha of salt-affected soils exist worldwide (Beek et al. 1980). More than 404,600 ha of soils in Kansas are classified as saline, sodic, or saline-sodic and are present in 84 out of 105 counties in Kansas (Reed and Sorenson 1997).

Salt-affected soils impact vegetation through adverse physiological effects and high levels of sodium degrade the physical structure of soil. Soil salinity results in the direct inhibition of plant growth or function due to osmotic stress, ion toxicity or decreased absorption of essential nutrients (Läuchli and Epstein 1990). High sodium levels often inhibit plant growth by giving rise to poor physical soil characteristics including low aggregate stability, impervious subsoil layers, low infiltration rates, low hydraulic conductivities, and soil surface crusting which may impede or prevent seedling emergence (Richards 1954; Läuchli and Epstein 1990; Rhoades 1990; Shainberg 1990).

Contamination of soil from oil and gas production activities is responsible for significant environmental damage throughout the Great Plains. Salt water (brine), consisting primarily of sodium chloride (NaCl), is commonly encountered during drilling operations. As a regulated waste product, brine cannot be indiscriminately discharged onto the land surface and is therefore reinjected into deep wells or discharged into onsite reserve pits after separation from oil. However, accidental discharges of these fluids onto the soil surface can result in an immediate loss of vegetation followed by increased soil erosion. Brine contamination can reduce forage production on rangelands, reduce crop yields on farmlands, and impact habitat for native flora and fauna (McFarland, Ueckert and Hartmann 1987; Auchmoody and Walters 1988). Reclamation of salt-affected areas is important to land owners, resource management agencies, and conservation organizations.

This study documents the presence of plant species on naturally occurring salt-affected soil at Cheyenne Bottoms, Kansas through quantitative analysis of *in situ* soil salinity and plant cover data. This study does not experimentally evaluate plant species for their use in the restoration or revegetation of salt-affected areas. However, the investigation of dominant plant species on salt-affected soil provides heuristic value for identifying potential species to be used in the restoration or revegetation of areas that have been degraded through oil and gas production activities.

Study Area

Cheyenne Bottoms is a 165 km^2 basin (Bayne 1977) located in the mixed-grass region of the Great Plains (Kuchler 1974) in Barton County, Kansas (38°29'N, 98°40'W) in the Smoky Hills Physiographic Province of central Kansas (Wilson 1978). The climate of this area is characterized by a 27.1°C mean July temperature, 13.4°C mean annual temperature, and 650.2 mm of annual precipitation of which 73% falls in April through September (Dodge et al. 1981).

The study area is The Nature Conservancy's 2942 ha Cheyenne Bottoms Reserve located adjacent to the northwest boundary of the 8036 ha state-owned Cheyenne Bottoms Wildlife Management Area. Plant communities of the study area include saltflat mixed prairie and grass lake playa. Saltflat mixed prairie is characterized by *Distichlis spicata* (inland saltgrass), *Hordeum jubatum* (foxtail barley), *Poa arida* (plains bluegrass), and *Sporobolus airoides* (alkali sacaton). Grass lake playa plant communities are characterized by *Agropyron smithii* (western wheatgrass) and *Buchloe dactyloides* (buffalo grass) (Lauver et al. 1999).

Salt deposits below Cheyenne Bottoms are responsible for soil salinity and surface deposits of salt. Subsurface salt deposits originate from the Hutchinson Salt member of the Wellington Formation formed during the Permian and lie between 9 m and 43 m below the surface. Data from oil well logs indicate that salt deposits are between 76.2 m and 91.4 m thick and contain 60 - 80% salt (Kulstad 1959). Soils in the study area are identified as Drummond silt loams (fine, mixed, superactive, thermic Mollic Natrustalfs). The Drummond silt loam is affected by sodium and soluble salts and exhibits salt accumulations at the soil surface (Dodge et al. 1981). The basin is remarkably flat with elevations throughout the study area ranging between 548 m and 550 m above sea level.

Methods

Four sites named McClain Lake, Rush Lake, Avocet Marsh, and Dead Lake were established within the study area to collect soil salinity data and sample vegetation. The sites are located within a 23 km^2 area. The sampled areas have never been tilled, but have been grazed by livestock for several decades. Soil salinity was determined from nine soil samples, each 20 cm in depth, randomly collected from each site in the study area in June 1998. A soil sampling depth of 20 cm was chosen for this study because it reflects the depth of the A horizon, consisting of silt loam, in the Drummond soil series where a majority of roots are found. A clay horizon extends below the A horizon to a depth of 75 cm (Dodge et al. 1981). Two samples, separated by 46 m, were taken from the McClain Lake site, two samples, separated by 126 m were taken from the Rush Lake site, and two samples, separated by 105 m, were taken from the Avocet Marsh site. Three samples were taken at random along a 140 m transect at the Dead Lake site. Samples #1 and #2 were separated by 120 m, while samples #2 and #3 were separated by 20 m. Soils were analyzed at the Kansas State University Soil Testing Laboratory for electrical conductivity (EC_e) and sodium adsorption ratio (SAR) by the saturation paste extract method (Rhoades 1982). Saline soils exhibit electrical conductivity values greater than 4 dS/m and SAR values less than 13, saline-sodic soils exhibit electrical conductivity values greater than 4 dS/m and SAR values greater than 13, and sodic soils exhibit electrical conductivity values less than 4 dS/m and SAR values greater than 13 (Richards 1954). Soils were classified *a posteriori* as saline, saline-sodic, or sodic (Table 1). Amelioration of soil salinity was not conducted prior to sampling efforts. Therefore, measurements of electrical conductivity and SAR represent natural salinity levels throughout the study area.

In order to directly compare soil salinity with vegetative cover at each soil sampling location, aerial percent cover for each plant species in a 1 m^2 quadrat surrounding each soil sample location (i.e. plot) was estimated in June and September 1998. Cover was estimated to the nearest 1% for each species in each plot. Species that exhibited cover less than or equal to 0.5% were assigned a cover value of 0.5%. Dominant plant species are defined as those species exhibiting at least 5% relative cover. Nomenclature of plant species follows the Flora of the Great Plains (Great

Table 1. Electrical Conductivity (ECe) and Sodium Adsorption Ratio (SAR) for soils collected at Cheyenne Bottoms, Kansas.

Site	SAR	ECe	(dS/m)	Classification
McLain Lake	(1)	18.3	4.1	saline-sodic
McLain Lake	(2)	5.1	0.7	non-saline
Rush Lake	(1)	14.4	2.1	sodiic
Rush Lake	(2)	6.2	1.5	non-saline
Dead Lake	(1)	1.8	1.2	non-saline
Dead Lake	(2)	19.1	2.7	sodic
Dead Lake	(3)	41.9	9.6	saline-sodic
Avocet Marsh	(1)	17.4	5.4	saline-sodic
Avocet Marsh	(2)	9.9	2.7	non-saline

Plains Flora Association 1986). Voucher specimens are deposited in the Ronald L. McGregor Herbarium at the University of Kansas.

Results and Discussion

A total of 20 plant species were recorded on saline-sodic soils within the study area (Table 2). Dominant species in spring include *Agropyron smithii* (20.4%), *Distichlis spicata* (29.8%)*, Poa arida* (5.8%) and *Sporobolus airoides* (42.6%). With the exception of *Euphorbia geyeri*, the cover of dominant species in fall was similar to the cover exhibited by these species in spring. Although *Hordeum jubatum* is a characteristic species of saltflat mixed prairies in the area (Lauver et al. 1999) and is present throughout much of Cheyenne Bottoms (Aschenbach 2000), it was not found at the soil sampling locations used in this study.

Ungar (1965; 1966) documented several of these species in his analysis of salt-affected plant communities of Kansas and Oklahoma. *D. spicata* is found in areas of the Big Salt Marsh of central Kansas with electrical conductivities (EC_e) ranging from 0.67 – 42.42 dS/m at a depth of 10 cm (Ungar 1965)

Table 2. Plant species and associated cover on salt-affected and non-saline soil at Cheyenne Bottoms, Kansas.

		Spring cover Soil:		Fall cover soil:	
Species	**Common Name**	**Salt-affected**	**Non-saline**	**Salt-affected**	**Non-saline**
Agropyron smithii	Western wheatgrass	20.4%	67.8%	15.6%	67.5%
Alopecurus carolinianus	Carolina foxtail	<1.0%	0.0%	0.0%	0.0%
Ambrosia psilostachya	Western ragweed	0.0%	2.0%	<1.0%	1.5%
Aster ericoides	Heath aster	<1.0%	<1.0%	<1.0%	<1.0%
Aster subulatus	Saltmarsh aster	<1.0%	<1.0%	1.0%	1.0%
Buchloe dactyloides	Buffalograss	<1.0%	20.0%	<1.0%	14.5%
Coreopsis tinctoria	Plains coreopsis	<1.0%	<1.0%	1.4%	0.0%
Distichlis spicata	Saltgrass	29.8%	22.8%	44.2%	22.8%
Eleocharis xyridiformis	Spikerush	2.0%	7.0%	<1.0%	16.0%
Eriochloa contracta	Prairie cupgrass	0.0%	0.0%	<1.0%	0.0%
Euphorbia geyeri	Sandmat	0.0%	0.0%	7.0%	0.0%
Hordeum pusillum	Little barley	1.0%	<1.0%	<1.0%	<1.0%
Iva annua	Marsh elder	3.6%	<1.0%	4.0%	<1.0%
Lepidium densiflorum	Peppergrass	<1.0%	0.0%	0.0%	0.0%
Plantago elongata	Slender plantain	<1.0%	0.0%	0.0%	0.0%
Poa arida	Slender plantain	5.8%	5.8%	6.2%	1.3%
Polygonum ramosissimum	Bush knotweed	0.0%	<1.0%	1.2%	<1.0%
Portulaca oleracea	Purslane	0.0%	0.0%	<1.0%	0.0%
Schedonnardus paniculatus	Tumblegrass	0.0%	0.0%	<1.0%	0.0%
Sporobolus airoides	Alkali sacaton	42.6%	0.0%	43.8%	0.0%

and in saline areas of northern Kansas and Oklahoma with EC_e ranging from 2.19-66.1 dS/m, also at a depth of 10 cm (Ungar 1966). *S. airoides* is known to invade the salt flats of the Great Salt Plains of Oklahoma and the Big Salt Marsh in Kansas where EC_e range between 35.7 dS/m and 49.8 dS/m (Ungar 1965; Ungar 1966), while *P. arida* is found at much lower salinities, ranging from 0.67-26.9 dS/m EC_e at the Big Salt Marsh (Ungar 1965) and at 1.18-18.4 dS/m EC_e in northern Kansas and Oklahoma (Ungar 1966).

While species such as *S. airoides* and *D. spicata* have been shown to grow better under saline conditions compared to nonsaline conditions (Grueb, Drolsom and Rohweder 1985; Aschenbach 2006), most plants, including some halophytes, tend to grow better on non-saline soil rather than on salt-affected soil (Ungar 1974; Ungar 1991). Although the low species cover exhibited by a majority of the species recorded in this study may be due to factors other than salinity (e.g. dispersal ability, disturbance, competition, herbivory, etc), their cover on salt-affected soil is much lower than on non-saline soil locations throughout the study area (Table 2). The species recorded in this study may be able to grow under greater levels of soil salinity than exhibited in the study area; however, absolute salt tolerances of these species are not evaluated here. A field or greenhouse experiment that subjects these species to increasing levels of soil salinity would be necessary in order to determine absolute salt tolerances.

This study does not experimentally evaluate plant species for their use in the restoration or revegetation of salt-affected areas. However, comparable salinity levels and species found in areas that have been degraded through oil and gas production activities suggest that the dominant species observed in this study deserve further attention as potential candidates for the restoration of salt-affected areas. Using a slightly different method of measuring electrical conductivity (i.e. EC 1:1) that is comparable with ECe, Kreher and McConnell (1998) recorded electrical conductivity values between 1.2 dS/m and 16.0 dS/m and SAR values between 0.9 and 19.1 at a depth of 10 cm in their analysis of brine scars at the Tallgrass Prairie Preserve in Oklahoma, while Harris et al. (1999) recorded electrical conductivity values of 2.9 - 16.2 dS/m at a depth of 10 cm in a similar study. McFarland, Ueckert and Hartmann (1987) recorded average EC_e values between 3 dS/m and 11 dS/m and SAR values between 5-16 at a depth of 45 cm in a soil analysis of an oil well reserve pit in west Texas.

Similarly, the species recommended for the revegetation of salt-impacted areas coincide with the dominant species found in this study. In their analysis of a reclaimed brine-contaminated area having SAR and electrical conductivity values similar to our study area, Halvorson and Lang (1989) found that *D. spicata* exhibited the highest vegetative cover of 12 species examined. In brine impacted areas, *S. airoides* was found to be least affected by toxic waters associated with fossil fuel processing that contain various chemical constituents in addition to brine (Skinner, Moore and Sexton 1984) and was recommended for revegetation of these areas (McFarland, Ueckert and Hartmann 1987). Halvorson and Lang (1989) found that although *A. smithii* cover was only 2.0% in a reclaimed brine contaminated area, it was second only to *D. spicata* in vegetative cover and it was also tolerant of toxic fossil fuel processing waters (Skinner, Moore and Sexton 1984).

In addition to salt tolerance, the dominant species observed in this study have additional characteristics that would make them suitable for the restoration of salt-affected areas. Many halophytes experience reduced seed germination at various levels of salinity (Ungar 1978; Woodell 1985). Therefore, once established, rhizomatous plant species such as the dominant grass species observed in this study, may be able to colonize saline environments where seed propagation may otherwise be inhibited (Shumway 1995; Pennings and Callaway 2000). In addition, since graminoids generally exhibit more extensive root systems and cover more soil surface area than forbs, establishment of these species may prevent further soil erosion. Lastly, the commercial availability of species such as *A. smithii* makes them a practical choice for land owners, resource management agencies, and conservation organizations that seek to revegetate areas impacted by brine contamination.

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