The Relation Between Soil Salinity and Site Productivity of a Coastal Bend Sudangrass Pasture

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ABSTRACT

A site with a history of patchy plant growth and salt spills from oil and gas drilling activities was studied to determine the relation between soil salinity and site productivity of a sudangrass (*Sorghum sudanense*) pasture. Soils were sampled and site productivity was evaluated along a 1600-foot transect. On sites with poor productivity, soil salinity values (by $EC_{1:1}$) were greater in the 36 to 48 inch depth than in upper depths. Site productivity related significantly (P = 0.05) to soil salinity by both linear and quadratic models, but the boundary line method was judged to be the best method for describing the relation.

KEY WORDS: Salt, sodium, boundary line

Patchy, nonuniform plant growth is common along the Coastal Bend region of south Texas. Often the lack of uniformly vigorous plant growth is attributed to soil salts, either originating naturally from water tables, or arising from leaks and spills from oil and gas drilling activities. Deleterious effects of salt can be either osmotic effects, general to all salts, or the effects of specific ions on specific plants (U.S. Salinity Laboratory Staff, 1954). The tolerance of plants to salt has been thoroughly investigated and relative salt-tolerance data is available for common crops (Rhoades and Miyamoto, 1990). Unfortunately most of the compiled data is based upon salinity as measured by electrical conductivity of a saturation extract (EC_e). Many laboratories have switched to 1:1, 1:2, or 1:5 soil:water extracts for simplicity (Texas Agricultural Extension Service, 1980), but the interpretation of such data can be difficult. In this study, soil salinity is reported as electrical conductivity of the filtrate of a 1:1 soil:water mixture ($EC_{1:1}$) and a regression is established allowing conversion between $EC_{1:1}$ and EC_e.

A site in Nueces County, Texas was chosen for study because of a history of nonuniform plant productivity, and the presence of gas wells and salt-water pipelines throughout the property. At the time of the study, the site was seeded to sudangrass, a moderately salt-tolerant crop (Rhoades and Miyamoto, 1990).

Plant response in laboratory studies is often linear with respect to a growth-limiting factor. However studies conducted under field conditions often show non-

Accepted 5 Feb 1992. *Corresponding author.

linear or weak, linear correlations between plant response and the experimental factor because factors other than the one in question come into play. A method of dealing with such data, termed the "boundary line" method , is gaining favor with field investigators (Sumner, 1987). By delineating the best response at each level of stimulus, the boundary line method estimates what the crop response to a variable would be if only that variable were limiting (Webb, 1972). The method has been used to formulate fertilizer recommendations based on soil test data.

This paper serves two objectives. It describes the relation between site productivity in a sudangrass pasture to soil salinity, and presents a useful outgrowth from that description. The outgrowth is a suggested role for the boundary line for describing plant response to soil salinity where salinity is limiting to plant growth unless some other factor supersedes the effects of salt.

MATERIALS AND METHODS

A field was chosen based on nonuniformity of plant growth. The soil was the Willacy-Clareville-Orelia association of nearly level, loamy and moderately sandy soils, with intermittent Victoria clay (Franki et al., 1965). A transect 1600 feet long was oriented through the field such that it intersected sites of good and poor plant vigor. Every 100 feet, and elsewhere as necessary, plant vigor was evaluated and soil samples were collected. Each sampling site was surveyed by profile leveling to determine relative elevation. Plant production varied markedly along the transect, ranging from dense stands of sudangrass over 5 feet tall, to spots with sparse vegetation less than 1 foot tall. On 21 July 1990, relative site productivity was assessed by assigning each site an index number between 1 and 5, similar to the range productivity evaluation system of Richardson et al. (1979). Productivity assessments from two investigators were averaged, then converted to percentage of the highest score. On 24 July 1990, 2-inch diameter soil cores were collected to a depth of 4 feet, at 1-foot increments, using a hydraulic sampler. All soils were analyzed for pH and for salt by $EC_{1:1}$. Six soils were analyzed for salt by both $EC_{1:1}$ and EC_e for comparison (U.S. Salinity Laboratory Staff, 1954; Rhoades, 1982). All soils were analyzed for organic matter (Nelson and Sommers, 1982) to identify factors other than salt (such as oil) that could limit plant growth. Selected samples were analyzed for individual cations by atomic absorption or flame emission spectrometry on ammonium acetate extracts.

RESULTS AND DISCUSSION

Site productivity did not correlate significantly to surface elevation ($r^2 = 0.01$), nor to the organic matter content ($r^2 = 0.00$) or pH of the upper foot of soil ($r^2 = 0.17$). Soil pH values in the surface foot can all be considered normal, ranging from 6.1 to 7.8. In subsurface horizons, pH ranged from 6.6 to 8.4. Organic matter ranged from 0.5 to 2.0% in the surface foot, and 0.03 to 1.8 in subsurface horizons. Subsurface organic matter was as high as 2.9% on a suspected oil-spill site near the transect.

Rather than the traditional unit of mmho/cm for EC, data are expressed in the newer S.I. unit, dS/m. The units are interchangeable, i.e., 1 mmho/cm = 1 dS/m. Site productivity index values and salinity data from 1:1 extracts are presented in Table 1. An inverse relationship between site productivity and soil salinity at the

36 to 48 inch depth, was observed over much of the transect, but not beyond the 1200 foot mark (Figure 1). Sudangrass is inhibited by EC_e of 2.8 dS/m (Rhoades and Miyamoto, 1990), which corresponds to an $EC_{1:1}$ value of about 1.4 dS/m (Figure 2). Only at the 3 to 4 foot depth did $EC_{1:1}$ values approach 1.4 dS/m. For this reason, salinity in the 3 to 4 foot depth is of particular interest for this study.

Table 1. Soil salinity as measured by electrical conductivity of a 1:1 extract and site productivity along a 1600-foot transect through a sudangrass pasture.

Site	Site Productivity	Soil Depth 0-12"	12-24"	24-36"	36-48"
	%	---------- dS/m	----------	----------	----------
0	32	0.16	0.57	0.17	0.29
25	15	0.16	0.16	0.15	0.20
50	62	0.17	0.16	0.16	0.16
100	32	0.16	0.17	0.17	0.16
200	10	0.32	0.41	0.57	0.86
250	10	0.29	0.19	0.59	0.46
300	15	0.34	0.41	0.47	0.83
350	10	0.28	0.29	0.38	0.51
400	62	0.19	0.15	0.17	0.15
450	45	0.15	0.16	0.17	0.19
500	62	0.20	0.20	0.29	0.21
600	87	0.20	0.26	0.25	0.21
700	62	0.20	0.18	0.22	0.29
750	10	0.22	0.48	0.54	1.47
800	62	0.26	0.29	0.33	0.39
900	100	0.22	0.14	0.16	0.15
950	32	0.18	0.24	0.37	0.46
1000	22	0.31	0.40	0.63	1.87
1050	10	0.26	0.43	1.03	2.40
1100	15	0.18	0.30	0.40	0.41
1200	45	0.12	0.29	0.34	0.47
1250	62	0.14	0.17	0.19	0.24
1300	32	0.17	0.18	0.16	0.18
1350	45	0.14	0.18	0.16	0.17
1400	32	0.22	0.18	0.18	0.18
1450	32	0.14	0.17	0.15	0.18
1500	22	0.16	0.16	0.17	0.23
1550	22	0.20	0.16	0.19	0.20
1600	22	0.14	0.16	0.14	0.17

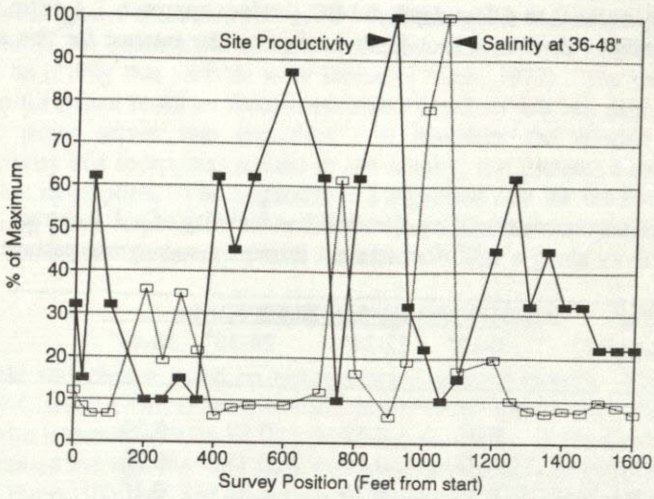

Figure 1. Site productivity and soil salinity ($EC_{1:1}$) along a 1600-foot transect through a sudangrass pasture.

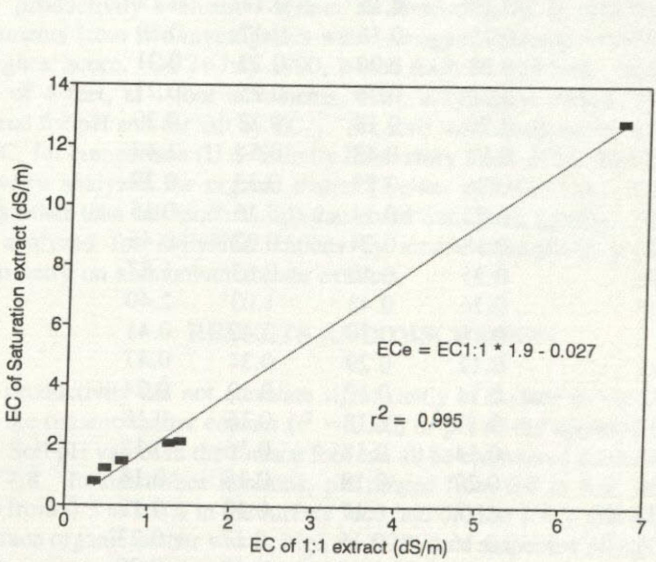

Figure 2. Linear regression relating electrical conductivity (EC) of saturation extract to EC of 1:1 extract.

Figure 3 shows the relation between site productivity and soil salinity as measured by $EC_{1:1}$ on samples taken from the 36 to 48 inch depth. Although site productivity relates significantly ($\underline{P}$ = 0.05) to $EC_{1:1}$ by linear regression, an inspection of the data (Figure 3) clearly reveals that a linear model would not adequately describe the relationship. Likewise, a quadratic regression model ($Y = 21.22 X - 66.83 X^2 + 57.54$) provides a significant ($\underline{P}$ = 0.05) fit, but is of limited practical utility because it implies an increase in productivity at very high salt levels (Figure 3). The weakness of the boundary line method is that it does not lend itself readily to statistical analysis. The strength of the method can be observed in Figure 3. The line predicts the maximum site productivity for a given level of $EC_{1:1}$. Productivity can be less than the boundary value if something other than salinity is limiting. Note that the boundary line is linear+plateau. The plateau indicates that once a certain X value is obtained, Y values are thereafter unaffected. Linear+plateau and quadratic+plateau lines are typical of models describing field fertility studies (Cerrato and Blackmer, 1990).

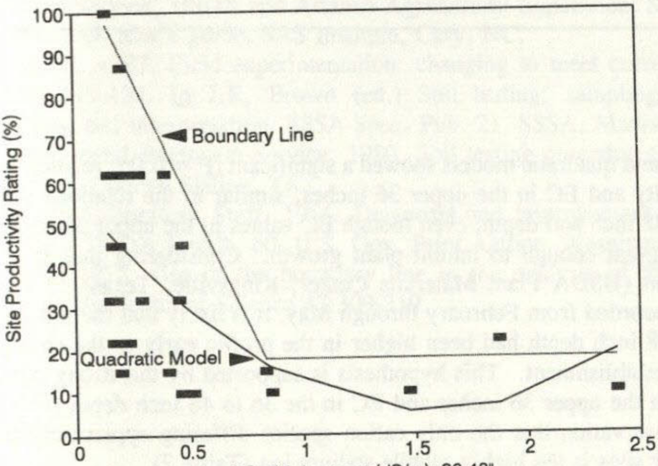

Figure 3. Relation between site productivity of a sudangrass pasture and soil salinity as measured by electrical conductivity (EC) of 1:1 extract. Boundary line and quadratic models are compared.

Table 2. Ammonium acetate extractable soil potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na) from the site of greatest productivity (Site 900) and two sites of low productivity (Sites 750 and 1050).

Site	Depth	K	Mg	Ca	Na
	inches	mg/kg			
900	0-12	433	323	2800	33
	12-24	265	339	2820	37
	24-36	286	470	3760	47
	36-48	257	457	3710	42
750	0-12	370	468	2170	126
	12-24	391	910	4180	630
	24-36	371	830	3360	870
	36-48	446	820	3040	1520
1050	0-12	439	563	2730	171
	12-24	424	900	4230	630
	24-36	440	890	3660	1160
	36-48	483	705	3280	1680

Both linear and quadratic models showed a significant ($\underline{P} = 0.05$) relation between site productivity and EC in the upper 36 inches, similar to the relations illustrated for the 36 to 48 inch soil depth, even though EC values in the upper 36 inches were probably not great enough to inhibit plant growth. Considering that at a nearby weather station (USDA Plant Materials Center, Kingsville, Texas) 13 inches of rainfall was recorded from February through May, it is likely that the salt measured in the 36 to 48 inch depth had been higher in the profile early in the spring at the time of crop establishment. This hypothesis is supported by the strong correlation between EC in the upper 36 inches and EC in the 36 to 48 inch depth ($r^2 = 0.80$), and by the observation that the only cation species differing appreciably between good and poor sites is the highly mobile sodium ion (Table 2).

CONCLUSION

Plant growth and vigor at the site was patchy, as is common on salt-affected soils. At the time of the study, salinity in the upper three feet of soil was not sufficiently high to explain the patchy growth. Samples taken from the 3 to 4 foot depth revealed high concentrations of salt. The boundary line technique as is used to describe field response to soil fertility was the best technique to describe the response to soil salinity. The boundary line, derived using only the greatest productivity value obtained from a given soil salinity level, can be described by a linear+plateau segmented model (SAS, 1985). The findings established that: 1) site productivity in a sudangrass pasture was related to soil salinity, even though the upper levels of soil were relatively salt-free; and 2) the boundary line method of describing plant response to soil fertility was an adequate and practical method to describe the relation between site productivity and soil salinity.

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