THE POTENTIAL OF SALTGRASS AS A FORAGE GRASS IRRIGATED WITH SALINE WATER

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ABSTRACT

The objective was to investigate the potential of saltgrass (*Distichlis spicata* (L.) Greene), a native halophyte, as a forage grass when irrigated with saline water. In a sandy loam, water containing 1,250, 2,500, 5,000 and 10,000 mg/L Total Dissolved Solids (TDS) was applied and, in a clay loam, water containing 1,250, 2,500, and 5,000 mg/L TDS was applied.

The sandy loam was more highly salinized than the clay loam soil, from sodium adsorption ratio and electrical conductivity measurements. In the sandy loam soil, mean yields were 3,674 kg/ha. Yields were highest at 2,500 mg/L, and decreased with increasing salinity. Yields were lower at 1,250 mg/L than at 2,500 mg/L due to weed competition. Plant sodium percentage increased and magnesium percentage decreased with increasing salinity. Plant calcium, potassium, phosphorus, crude protein, and *in vitro* digestibility percentages were generally not affected.

The clay loam was not completely salinized during the experiment. Accordingly, mineral, crude protein, and digestibility percentages, and dry forage yields, were generally not affected by salinity. Mean yields in the clay loam were 6,968 kg/ha.

Minerals and crude protein were generally supplied by the saltgrass in adequate amounts for animal nutrition, except phosphorus. Sodium percentages averaged 1.08 %, but were not thought to be detrimental. Digestibility was generally low. Overall, it was concluded that saltgrass has potential to be irrigated with high salinity water when other forages are not available.

Key words: Saltgrass, *Distichlis spicata* (L.) Greene, salinity, dry forage yields, *in vitro* dry matter digestibility, crude protein percentage, sodium percentage, calcium percentage, phosphorus percentage, potassium percentage, magnesium percentage

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INTRODUCTION

In arid regions of the western United States, there is an increasing demand for water for domestic and industrial purposes, as well as for irrigated agriculture. Much of the water available to meet this demand is in underground supplies. For example, there are approximately 20 billion acre-feet of water in underground supplies in New Mexico, as estimated by the Geological Survey (United States Department of Interior, 1976). However, a large proportion of this water is saline. Only 3 billion acre-feet of the ground water in New Mexico is classified as fresh water (less than 1,000 mg/L of Total Dissolved Solids (TDS)), while only 1.4 billion acre-feet is classified as slightly saline (1,000-3,000 mg/L TDS). The remainder, more than 15 billion acre-feet, contains more than 3,000 mg/L TDS. In addition, ground water is being withdrawn from the underground supplies faster than it can be recharged in some areas of New Mexico. In some of these areas, there is an encroachment of saline water and a consequent lowering of water quality.

Saline water cannot readily be used in traditional irrigated agriculture, or for domestic or industrial uses, since these systems require relatively non-saline water. Desalinization of these waters is at present costly, and requires a considerable energy input; it is therefore important to investigate the possiblities of using the saline water in irrigated agriculture, so that some of the fresh water supplies can be conserved for alternative uses.

The development of crops that can tolerate high levels of salinity could be extremely valuable. This could be achieved either by developing salt tolerant varieties of traditional crops, as is being attempted with barley (Epstein, 1976), or by developing new crops from species that already have a high degree of salt tolerance (Mudie, 1974). A native species that appears to have considerable potential as a forage crop is saltgrass (*Distichlis spicata* (L.) Greene).

Saltgrass is a grass common throughout much of the United States and is found in all states west of the Mississippi except Arkansas and Louisiana (Nielsen, 1956). Two varieties have been described (Gould, 1968). *Distichlis spicata* var. *spicata* is frequently found on salt flats and brackish ponds in coastal areas, while *D. spicata* var. *stricta* (Torr.). Beetle is more common on alkaline and saline sites in inland areas.

Saltgrass has very broad tolerance to a wide range of salinities. It has been observed to grow in soil with salt concentrations from 300 to 56,000 mg/L TDS (Hunt and Durrell, 1966; Ungar *et al.*, 1969). The upper limit is considerably more saline than seawater (approximately 35,000 mg/L TDS), although the plant takes on a stunted form at these concentrations. Hansen *et al.* (1976), using saltgrass collected from a salt flat in Utah, treated samples with Hoagland's solution containing different salt concentrations, and observed that the optimum salinity was 15,000 mg/L TDS. Saltgrass has also been found to grow under a wide range of soil conditions. Tolstead (1942) observed it growing in soils high in carbonates and bicarbonates, Flowers (1934) and Ungar (1970) found it in soils high in sulfates, and Ungar (1965) and Ungar *et al.* (1969) found it in soils high in chlorides. In general, saltgrass grows in alkaline soils, with the soil pH ranging from 6.8 to 9.2 (Ungar, 1974). Ungar (1974) also reported that saltgrass has been observed growing in soils of different textures, from sands and gravels to clays, and in soils where the organic matter varied from as little as 0.4% to as high as 14.7%.

There is considerable potential for high yields of saltgrass under saline conditions. The productivity of saltgrass growing in the salt marshes of Long Island was measured at 647.5 g/m^2, which can be translated to a dry matter yield of 2.88 tons/acre (Udell et al., 1969). In addition, high rates of net photosynthesis have been observed (Detling and Klikoff, 1973). Kemp and Cunningham (1981) observed rates as high as 2 mg $CO_2 . m^{-2} . s^{-1}$ under optimum conditions, and rates of 0.8 $mg . m^{-2} . s^{-1}$ when saltgrass was grown at 30,000 mg/L TDS. Saltgrass is a C-4 species (Bender and Smith, 1973), and these photosynthetic rates are similar to rates observed in the highly productive C-4 species, corn and sugar cane.

Very little information is available on the forage quality of saltgrass. Udell et al. (1969) reported a protein content of 9.6%, but they did not state at which growth stage. Hansen et al. (1976) studied the protein content throughout the shole season and observed that it dropped from 15% on 1 April to 5% on 30 July. Other forage quality factors were measured by Udell et al. (1969), and they found that in addition to a protein concentration of 9.6%, carbohydrate concentration was 48.0%, crude fiber 34.9%, ash 5.5%, and fat 1.7%. These figures are very similar to early-bloom timothy hay (NAS, 1969), which is considered very good quality grass hay.

Overall, saltgrass is adapted to a wide range of conditions and apparently can produce good yields of forage of sufficient quality for livestock grazing. Accordingly, the objective of this study was to investigate the potential of saltgrass as a forage crop in pastures irrigated with saline water.

MATERIALS AND METHODS

Two sets of experiments were conducted to determine the effect of salinity on yield and quality of saltgrass. An initial experiment was conducted under greenhouse conditions at the Fabian Garcia Horticultural Farm to determine the mineral and crude protein percentages to be expected. Two different soil types were used. The first was a Glendale clay loam (fine-silty, mixed (calcareous), thermic Typic Torrifluvent), and the second was a Brazito very fine sandy loam (mixed, thermic Typic Torripsamment). Selected characteristics of both soils are given in Table 1.

Plastic pots, 20 cm in diameter, were filled with 5,000 g of soil. Each pot was planted with 50 g of saltgrass rhizome material. The rhizomes were collected in the vicinity of the Mesilla Dam, approximately 10 km southwest of Las Cruces. The saltgrass was planted on 9 February, 1981. The pots were watered with normal tap water every 3 or 4 days until 24 June. Pots were fertilized with 15-30-15 fertilizer ($N-P_2O_5-K_2O$) on 10 March, 10 April and 10 May for a total of 151 kg N/ha, 130 kg P/ha, and 125 kg K/ha.

On 24 June, the saltgrass in each pot was cut to 2.5 cm above the soil surface to standardize the plants. Pots were then watered with water of four different salinities, 1,000, 2,500, 5,000, and 10,000 mg/L Total Dissolved Solids (TDS). Water of the required salinities was made by mixing NaCl and $CaCl_2$ in the proportion of 85 % to 15 % with tap water (600 mg/L TDS). Water was applied every 2 to 4 days to maintain the soils at or near field capacity. In the pots containing the sandy loam soil, there were four replications of each of the four salinity treatments arranged in a randomized block design. Within each replication, a treatment consisted of three pots. For the clay loam soil, the arrangement was similar, except a treatment within each replication consisted of two pots.

Table 1. Soil analysis before the start of the experiments for the clay loam soil and the sandy loam soil.

Characteristic	Soil type	
	Glendale clay loam	Brazito sandy loam
pH (soil reaction)	7.83	7.59
Total soluble salts, g/kg	1.80	1.30
Exchangeable sodium, g/kg	33.0	10.0
Organic Matter, g/kg	14.7	15.3
Nitrate-N (water-soluble), mg/kg	13.60	5.10
Phosphorus (sodium bicarbonate extracted), mg/kg	0.53	1.20
Potassium (water-soluble), mg/kg	22.00	38.50

The saltgrass was harvested on 4 August, and again on 30 September, 1981. At each harvest, the saltgrass was clipped 2.5 cm above the soil surface. The plant material was dried at 70 C in a forced air oven, and weighed for determination of dry forage yields. The oven-dried samples were then ground in a Wiley mill to pass through a 1 mm screen, and were subjected to forage quality analyses.

For determination of phosphorus, calcium, potassium, magnesium and sodium percentages, 1 g samples of dried, ground, plant tissue were digested using nitric and perchloric acid digestion. An Auto-analyzer (Technicon Auto-Analyzer II) was used to obtain the percent elemental phosphorus by the molybdophosphoric blue color procedure. An atomic absorption spectrophotometer (Perkin-Elmer 403) was used to obtain the percentages of calcium, magnesium, potassium, and sodium. For determination of crude protein, 0.2 g samples of dried, ground, plant material were digested using a micro-Kjeldahl sulfuric acid digestion technique using a block digestor (Technicon BD-40). The auto-analyzer was then used to analyze the digested samples for percent total nitrogen, which was multiplied by 6.25 for calculation of crude protein in the standard manner.

Field experiments were conducted at the Plant Science Research Center, 13 km south of Las Cruces. Two sites were chosen, one with a Glendale clay loam soil and the other with a Brazito sandy loam soil. These soils were the same as those used in the greenhouse experiments, and the results of the soil test taken before establishment of the plots are shown in Table 1.

Sixteen plots were established at the sandy loam site. Each plot was 3 m wide and 6 m long, and a space of 3 m was left between plots to reduce the possibility of water moving into a plot from an adjacent plot. Saltgrass rhizome material was collected near the Mesilla Dam, and rhizomes were planted approximately 30 cm from each other in rows 30 cm apart. The sandy loam plots were planted in the fall of 1980 and allowed to become well-established before treatments started. The plots were irrigated with normal irrigation water during the establishment phase. Plots were fertilized on 20 April, 1981 with 16-8-8 ($N-P_2O_5-K_2O$) fertilizer using a Gandy fertilizer spreader at the rate of 56 kg N/ha, 11 kg P/ha and 21 kg K/ha to aid in establishment. Weed control during this time was by hand-pulling and hoeing. The saltgrass was trimmed on 2 July, 1981 at a cutting height of 10 cm using a circular blade mower to standardize the plots.

The salinity treatments were started in the sandy loam plots on 17 July, 1981. The four salinities were 1,250, 2,500, 5,000, and 10,000 mg/L TDS, and there were four replications of each salinity arranged in a randomized block design. Water was mixed by adding NaCl and $CaCl_2$ to normal irrigation water in a tanker truck with a capacity of 4730 L. The proportions of NaCl and $CaCl_2$ added were 85 % and 15%, respectively. The electrical conductivity and sodium adsorption ratio of the waters used are shown in Table 2. At each irrigation, a 6.7 cm depth of water was applied. Irrigation dates in 1981 were 17, 23, and 30 July, 14 and 21 August, and 8 December. Immediately after the first irrigation with saline water, the saltgrass was trimmed on 21 July at a 10 cm cutting height to standardize the plots. On 30 July, fertilizer was added as before at the rate of 56 kg N/ha, 11 kg P/ha, and 21 kg K/ha. The first harvest was taken on 21 August when the plants had reached anthesis using a circular blade mower at 15 cm cutting height. The area harvested was 1.8 m^2. Sub-samples were dried at 70 C in a forced air oven and weighed for determination of dry forage yield. Samples were ground using a Wiley mill to pass through a 1 mm screen and were retained for forage quality analyses. No further harvests were taken in 1981 as there was very little growth after this date.

Table 2. Electrical conductivity and sodium adsorption ratio of water of four different salinities and normal irrigation water.

Salinity	Electrical conductivity	Sodium adsorption ratio
(mg/L)	mmho/cm	
1,250	2.1	7.9
2,500	4.2	16.0
5,000	8.4	27.8
10,000	16.8	45.5
804 (well water)	1.2	2.9

In 1982, saline water was applied to the sandy loam plots on 11, 18, and 25 April, 2, 9, 23, and 30 May, 13, 20, and 27 June, 11, 18, and 25 July, 8, 15, 22, and 29 August, 5 and 19 September, and 3 and 10 October. At each irrigation, a 6.7 cm depth of water was applied, and a total of 141.3 cm was applied during the growing season. The plots were fertilized with 16-8-8 fertilizer (N-P_2O_5-K_2O) at the rate of 35 kg N/ha, 7 kg P/ha, and 13 kg K/ha on 29 March and again on 3 June. A liquid nitrogen fertilizer containing 32 % N was applied in the irrigation water on 16 July, September, and October at the rates of 35, 66, and 16 kg N/ha, respectively. A total of 187 kg N/ha was applied during the 1983 growing season. Weed control was again by hand-pulling and hoeing throughout the season. In addition, bermudagrass was controlled by spot treatments of Roundup (glyphosate) throughout the season. The plots were divided into two halves for two different cutting schedules. In one half, the saltgrass was harvested at anthesis on 10 August and 16 October. In the other half, the saltgrass was harvested post-anthesis on 23 August. Post-anthesis was one to two weeks after the anthesis stage and was during early seed-filling. A second harvest was not taken at the post-anthesis stage since there was no further growth after this date. Plots were harvested using clippers at 15 cm cutting height from areas of 1 m^2 in each half of each plot. The grass was dried at 70 C in a forced air oven, weighed for determination of dry forage yields and ground and retained for forage quality analyses.

In 1983, saline water was applied to the sandy loam plots on 18 and 25 April, 3, 9, 13, 23, and 30 May, 7, 10, 16, 23, and 28 June, 7, 14, 21, and 27 July, 2, 11, 17, and 26 August, and 2 September. A total of 141.3 cm was applied during the growing season. Prilled urea (45% N) was applied on 21 April at the rate of 224 kg N/ha, and liquid nitrogen fertilizer (32%N) was applied in the irrigation water on 3 May and 14 July at rates of 90 and 45 kg N/ha, respectively. A total of 359 kg N/ha was applied during the growing season. Saltgrass was harvested at anthesis on 30 June and 24 August, and at the post-anthesis stage on 13 July and 7 September. Weed control up to the first harvest was by hand-pulling, but weeds were not controlled after this time so that the effect of weed competition on saltgrass yields at the four different salinities could be determined. The percentage of each plot that was overtaken by bermudagrass was estimated on 26 May, 11 July, and 7 September. In addition, the percentage of weeds in the areas not overtaken by bermudagrass was estimated for each plot on 7 September. Harvests were taken in areas not infested with bermudagrass and other weeds were removed at harvest.

Twelve plots were established in the clay loam soil. Plots were 3 m x 6 m, and a space of 2.5 m was left between plots. Rhizomes were planted in the fall of 1980, but did not establish well due to cold temperatures and were replanted in the spring of 1981. During establishment, the plots were irrigated with normal irrigation water. The plots were fertilized with 16-8-8 fertilizer ($N-P_2O_5-K_2O$) on 30 July at the rate of 56 kg N/ha, 11 kg P/ha, and 21 kg K/ha. The saltgrass was trimmed at a 10 cm cutting height on 13 August to standardize the plots.

The salinity treatments were started in the clay loam plots on 21 August, 1981. Three salinities were used. The salinities were 1,250, 2,500, and 5,000 mg/L TDS. The 10,000 mg/L treatment was not used in the clay loam plots, because it was expected that the soil permeability to rainfall would quickly become limiting (O'Connor et al., 1980). There were four replications of each treatment in a randomized block design. Water was mixed and applied in the same way as for the sandy loam plots. No harvests were taken in 1981 as there was very little growth after the standardization cut on 13 August.

In 1982, saline water was applied to the clay loam plots on 16, 22, and 29 April, 7, 13, and 24 May, 4 June, 2 and 14 July, 1 and 26 August, 9 September, and 13 October. A total of 87.5 cm was applied during the 1982 growing season. The plots were fertilized on the same dates at the same rates as in the sandy loam plots in 1982. A total of 187 kg N/ha was applied during the season. Two different cutting schedules were used. Half of each plot was harvested when the saltgrass reached anthesis on 14 May, 23 June and 11 August. The other half was harvested at the post-anthesis stage on 21 May, 16 July, and 15 September. The saltgrass was harvested from a 1 m^2 area in each half of the plot using clippers.

In 1983, saline water was applied to the clay loam plots on 20 April, 13 and 30 May, 10 and 29 June, 7 and 19 July, 3 and 18 August, and 13 September. A total of 67.3 cm was applied during the season. Urea (45% N) was applied on 21 April at the rate of 112 kg N/ha. As in the sandy loam plots, weeds were controlled by hand-pulling until the first harvest and were then left uncontrolled to determine the effect of weed competition on saltgrass yields. The percentage of each plot that was overtaken by bermudagrass was estimated on 26 May, 11 July, and 7 September. Harvests at the anthesis stage were taken on 27 June and 26 August, and harvests at the post-anthesis stage were taken on 13 July and 12 September. Hand-clippers were used to harvest the saltgrass at 15 cm cutting height. Harvests were taken in areas not infested with bermudagrass.

After all harvests, dried, ground, samples were retained for forage quality analyses. Phosphorus, calcium, potassium, magnesium, sodium, and crude protein percentages in the tissue were analyzed for each harvest using the same methods described for the greenhouse experiments. In addition, *in vitro* dry matter digestibility was determined for the 23 August, 1982, harvest for the sandy loam plots, and for the 14 May and 23 June, 1982, harvests for the clay loam plots. Digestibility percentages were obtained using a modified two-stage *in vitro* technique (Tilley and Terry, 1963).

Sodium adsorption ratio and electrical conductivity of the soil were measured throughout the experiment to determine the effects of the salinity treatments on the soil. Soil samples of the top 15 cm of the soil profile were taken on 26 March, 1981; 6 April, 30 June, 19 August, and 19 October, 1982; and 11 April, 6 July, and 24 August, 1983 in the sandy loam plots. In the clay loam plots, samples were taken on 26 March, 1981; 14 April, 19 August, and 19 October, 1982; and 15 April, 7 July, and 2 September, 1983. In addition, on the 1983 dates, samples were taken in 15 cm increments from the soil surface to a depth of 60 cm. Sodium adsorption ratio and electrical conductivity measurements were made in the Soil and Water Testing Laboratory.

RESULTS

Greenhouse experiments

Mineral percentages, crude protein percentage, and dry forage yield of saltgrass grown in the greenhouse using water of four different salinities are shown for the Brazito sandy loam soil in Table 3 and for the Glendale clay loam soil in Table 4. Two harvests were taken for each soil type, on 4 August and 30 September, 1981. The associated analyses of variance are shown in Appendix Tables 1 and 2.

Calcium percentages were not significantly affected by salinity treatment at any harvest and were generally just below or in the normal range of 0.4 to 1.0 % for grasses (McDonald et al., 1973). Magnesium percentages were significantly affected ($P<0.01$) by salinity treatment only at the first harvest for the sandy loam soil. In this case, magnesium percentage declined in a linear manner with increasing levels of salinity (see Appendix Table 1). The normal range for magnesium in pasture grasses is from 0.12 to 0.25 % (McDonald et al., 1973), so the values obtained were just below normal or at the low end of the normal range. Potassium percentages were not significantly affected by salinity treatments, except at the first harvest for the clay loam soil. In this case, there were significant linear and quadratic effects (Appendix Table 2). Potassium percentages observed were generally slightly below normal or at the low end of the normal range of 1.2 to 2.8 % (McDonald et al., 1973). Sodium percentages were very high, with mean values above 1.0 %. Sodium percentage was significantly affected by salinity treatment only at the first harvest for the clay loam soil. In this case, only the quadratic effect was significant (Appendix Table 2). Phosphorus percentages were not affected by salinity at any harvest and were in the low range of below 0.2 % (McDonald et al., 1973).

Table 3. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass grown in the greenhouse with four levels of salinity, Brazito sandy loam soil, 4 August and 30 September, 1981.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
-----mg/L-----	%						---mg/cm^2---
Harvest 1 (4 August)							
1,000	0.35	0.13	1.20	1.52	0.08	10.62	13.27
2,500	0.40	0.13	1.05	1.50	0.08	10.92	9.77
5,000	0.44	0.11	1.03	1.39	0.07	12.19	11.96
10,000	0.46	0.09	0.95	1.62	0.07	12.62	11.08
Mean	0.41	0.11	1.05	1.51	0.08	11.59	11.52
	ns	**	ns	ns	ns	*	ns
C.V.%	20.95	8.27	26.41	17.22	7.53	6.42	21.85
Harvest 2 (30 September)							
1,000	0.33	0.12	1.10	1.12	0.10	6.34	7.50
2,500	0.34	0.11	1.25	1.04	0.11	7.47	6.97
5,000	0.61	0.11	1.14	1.32	0.12	7.51	5.14
10,000	0.35	0.11	1.28	0.95	0.09	6.67	5.09
Mean	0.41	0.11	1.18	1.14	0.10	7.00	6.16
	ns	ns	ns	ns	ns	ns	**
C.V.%	43.30	21.40	14.18	24.45	15.87	10.13	12.53

ns = non-significant
*, ** = significant at 5% and 1% levels of probability, respectively.

Table 4. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass grown in the greenhouse with four levels of salinity, Glendale clay loam soil, 4 August and 30 September, 1981.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
-----mg/L-----				-%-			---mg/cm^2---
Harvest 1 (4 August)							
1,000	0.37	0.13	0.92	1.64	0.07	12.89	8.39
2,500	0.40	0.13	0.97	1.37	0.07	12.46	9.80
5,000	0.44	0.11	1.83	1.35	0.07	12.13	8.44
10,000	0.55	0.13	1.87	1.74	0.07	12.30	8.63
Mean	0.43	0.12	1.40	1.52	0.07	12.45	8.81
	ns	ns	**	**	ns	ns	ns
C.V.%	21.29	30.47	23.52	9.67	13.54	7.45	12.39
Harvest 2 (30 September)							
1,000	0.56	0.11	1.44	1.50	0.12	7.55	10.32
2,500	0.60	0.13	1.23	1.19	0.12	6.13	9.06
5,000	0.48	0.14	1.23	1.18	0.11	6.52	8.27
10,000	0.50	0.11	1.29	1.24	0.13	6.66	5.55
Mean	0.54	0.12	1.30	1.29	0.12	6.76	8.28
	ns	ns	ns	ns	ns	ns	*
C.V.%	22.79	26.95	13.30	11.86	14.28	7.55	20.92

ns = non-significant
** = significant at the 1% level of probability

Crude protein percentages were relatively high at the first harvest for both soils, probably because of the addition of N fertilizer before this harvest. There was a significant ($P<0.01$) linear effect of salinity on crude protein percentage at the first harvest for the sandy loam soil (Appendix Table 1). Percentages were relatively low at the second harvest for both soils and were not affected by salinity treatment.

Dry forage yields were not affected by salinity treatment at the first harvest for either soil, but were significantly affected at the second harvest for both soils. For the sandy loam soil, there was a significant linear and quadratic effect, while for the clay loam soil, there was a significant linear effect only (Appendix Tables 1 and 2). The difference between harvests was presumably because of greater salinization of the soil by the time of the second harvest.

Overall, there were few consistent effects of the salinity treatments on mineral or crude protein percentages. Phosphorus percentages were low, while magnesium, potassium, and calcium percentages were generally at the low end of the normal range. Sodium percentages were very high. Crude protein percentages were relatively high at the first harvest, but relatively low at the second harvest. Dry forage yields were significantly reduced by increasing salinity at the second harvest for both soils.

Field experiments

Soil salinity. Measurements of sodium adsorption ratio (SAR) and electrical conductivity (EC) of the soil were taken throughout the experiment to determine the effect of the salinity treatments on the salinity and sodicity of the soil. The SAR and EC in the top 15 cm of the soil profile are shown in Figs. 1 and 2, respectively, for the sandy loam soil. The data are given in Appendix Tables 3 and 4. In general, the SAR values in

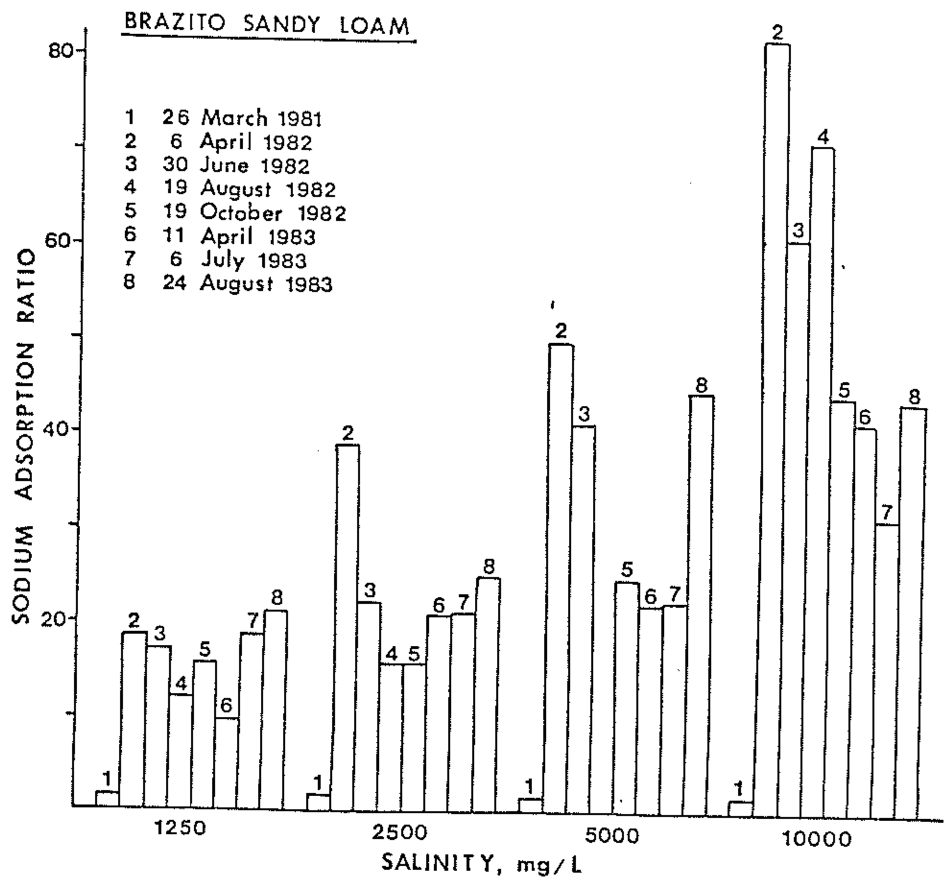

Fig. 1. Sodium adsorption ratio in top 15 cm of soil profile with four levels of salinity on eight dates, Brazito sandy loam soil.

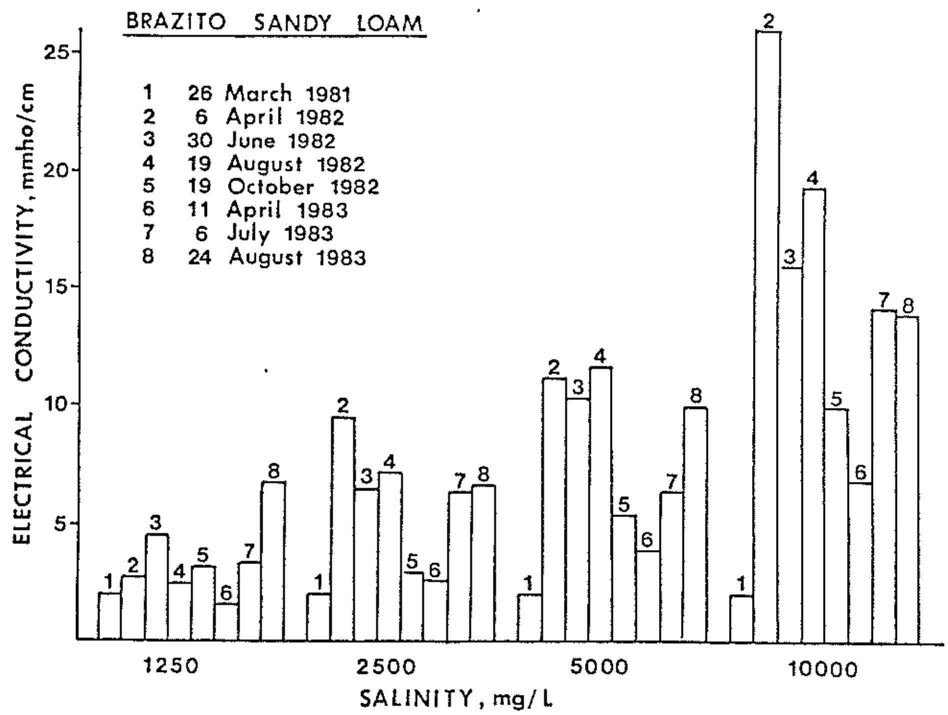

Fig. 2. Electrical conductivity in top 15 cm of soil profile with four levels of salinity on eight dates, Brazito sandy loam soil.

the sandy loam soil were proportional to the SAR values of the applied water. Mean SAR values in the top 15 cm of the sandy loam soil during 1982 and 1983 were 16.18, 22.64, 34.19, and 53.72, while SAR values of the applied water were 7.9, 16.0, 27.8, and 45.5 for the salinity treatments 1,250, 2,500, 5,000, and 10,000 mg/L TDS, respectively. Similarly, mean EC values in the top 15 cm of the sandy loam soil during 1982 and 1983 were 3.48, 4.72, 8.42, and 15.23 mmho/cm, while EC values of the applied water were 2.1, 4.2, 8.4, and 16.8 mmho/cm for the salinity treatments of 1,250, 2,500, 5,000, and 10,000 mg/L, respectively.

In 1983, measurements were also made in 15 cm increments down to a depth of 60 cm in the soil profile. The SAR and EC for each depth are shown in Figs. 3 and 4, respectively, for the sandy loam soil, and the data are given in Appendix Tables 5 and 6. Again, the values shown for each depth were generally proportional to the values of the applied water. The profiles suggest that the SAR and EC in the sandy loam soil were similar to the SAR and EC of the applied water throughout the effective rooting depth of the saltgrass.

Considerable variation in both SAR and EC was observed in the sandy loam soil, particularly in the top 15 cm of the profile. These variations were attributed primarily to differences in rainfall patterns. For example, the values on 6 April, 1982 were relatively high. No rainfall had been recorded for 40 days before samples were taken and water in the profile had therefore evaporated leading to a concentration of the salt. Conversely, the values on 11 April, 1983 were relatively low. In this case, 1.2 cm of rainfall fell during the week before samples were taken, thus diluting the salt concentration and moving salts further down the soil profile. In addition, considerable variation was observed within treatments, since the

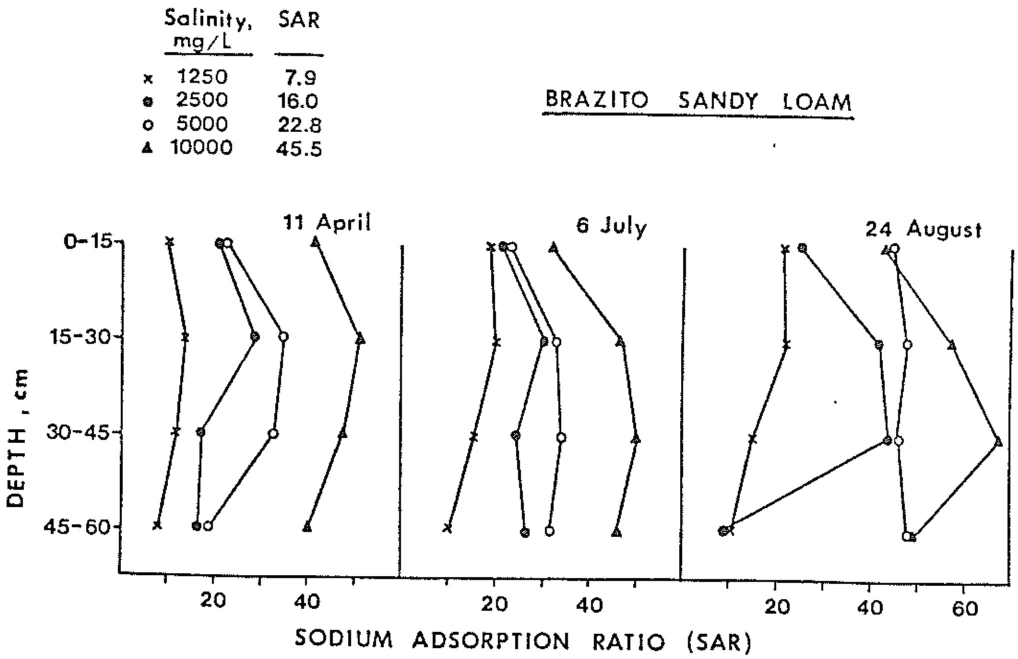

Fig. 3. Sodium adsorption ratio at four depths in soil profile with four levels of salinity on three dates, Brazito sandy loam soil, 1983.

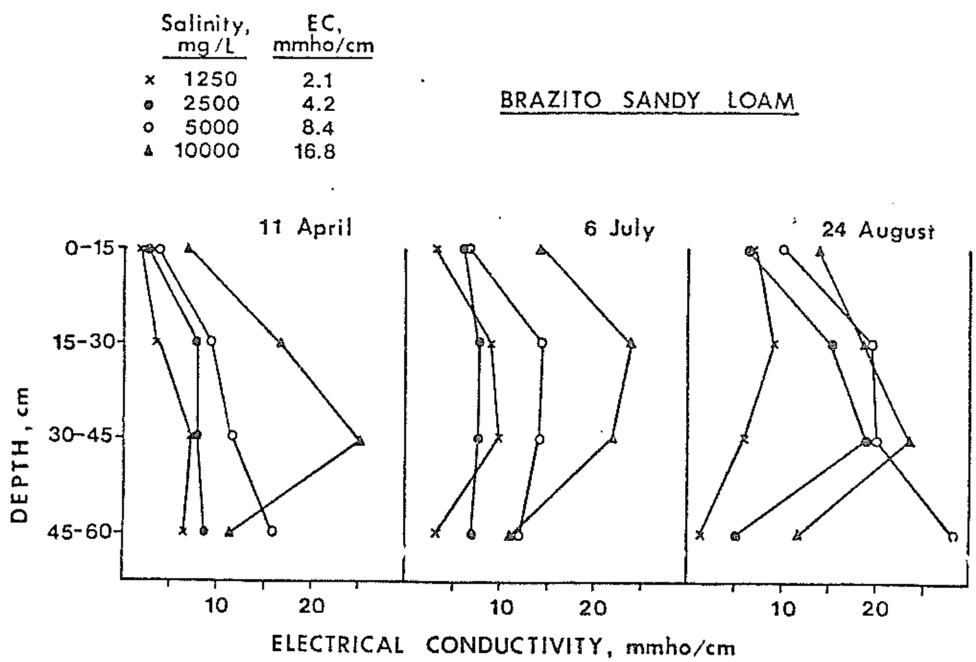

Fig. 4. Electrical conductivity at four depths in soil profile with four levels of salinity on three dates, Brazito sandy loam soil, 1983.

coefficients of variation for SAR and EC were 29.0 and 35.6%, respectively, for the sandy loam soil.

The SAR and EC in the top 15 cm of the clay loam soil are shown in Figs. 5 and 6, respectively, and the data are given in Appendix Tables 7 and 8. Mean SAR values were lower than they were in the sandy loam soils and large differences in SAR among the salinity treatments were not observed until towards the end of the treatment period. Mean SAR values were 10.30, 13.79, and 19.24 for the salinity treatments of 1,250, 2,500 and 5,000 mg/L TDS, respectively. Similarly, mean EC values were lower than in the sandy loam soils, with values of 3.52, 4.43, and 7.06 mmho/cm at salinities of 1,250, 2,500, and 5,000 mg/L, respectively. The lower SAR and EC values were presumably due to the greater buffering capacity of the clay loam soils and because less water was applied to these plots due to the greater water-holding capacity of the soil. During 1982 and 1983, 282.6 cm of water were applied to the sandy loam soils, while only 154.8 cm were applied to the clay loam soil.

The SAR and EC at four depths in the clay loam soil are shown in Figs. 7 and 8, respectively, and the data are given in Appendix Tables 9 and 10. Although SAR and EC values were proportional to the SAR and EC of the applied water, respectively, the profiles suggest that the soil was not completely equilibrated with the applied water. In particular, the SAR values at lower depths in the profile were less than the SAR of the applied water. Coefficients of variation for SAR and EC in the clay loam soil were 16.7 and 17.2%, respectively, lower than in the sandy loam soils.

<u>Forage quality and yield--Brazito sandy loam soil</u>. Five harvests were taken at anthesis for the sandy loam soil. Mineral percentages, crude protein percentages, and dry forage yields for each salinity level are

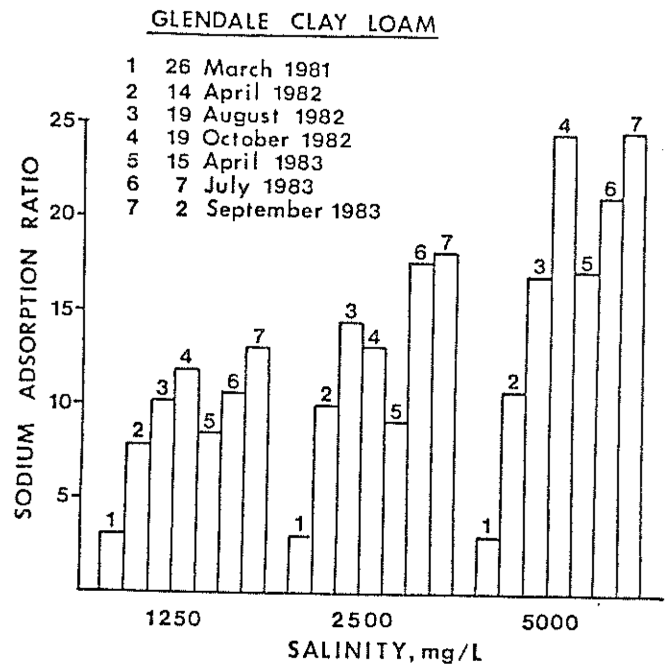

Fig. 5. Sodium adsorption ratio in top 15 cm of soil profile with three levels of salinity on seven dates, Glendale clay loam soil.

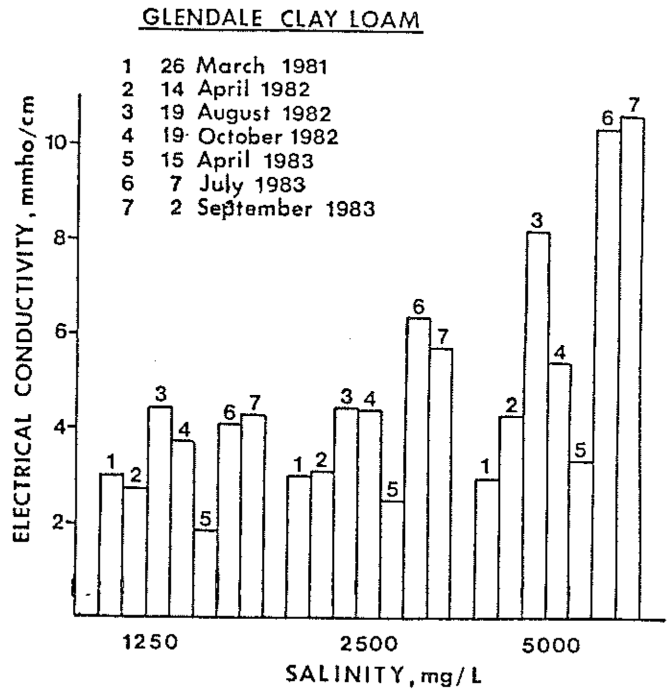

Fig. 6. Electrical conductivity in top 15 cm of soil profile with three levels of salinity on seven dates, Glendale clay loam soil.

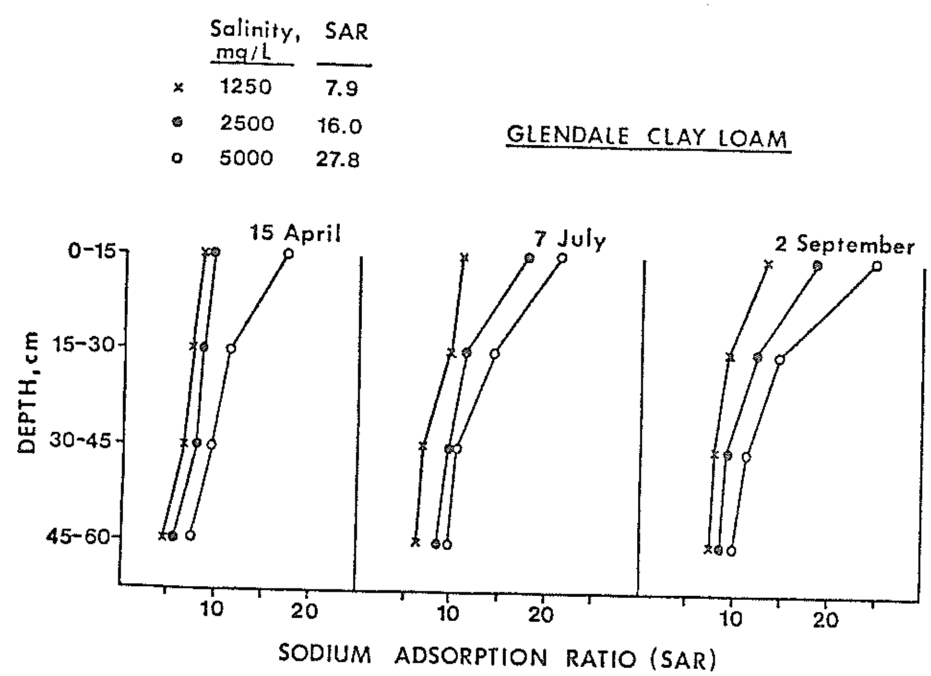

Fig. 7. Sodium adsorption ratio at four depths in soil profile with three levels of salinity on three dates, Glendale clay loam soil, 1983.

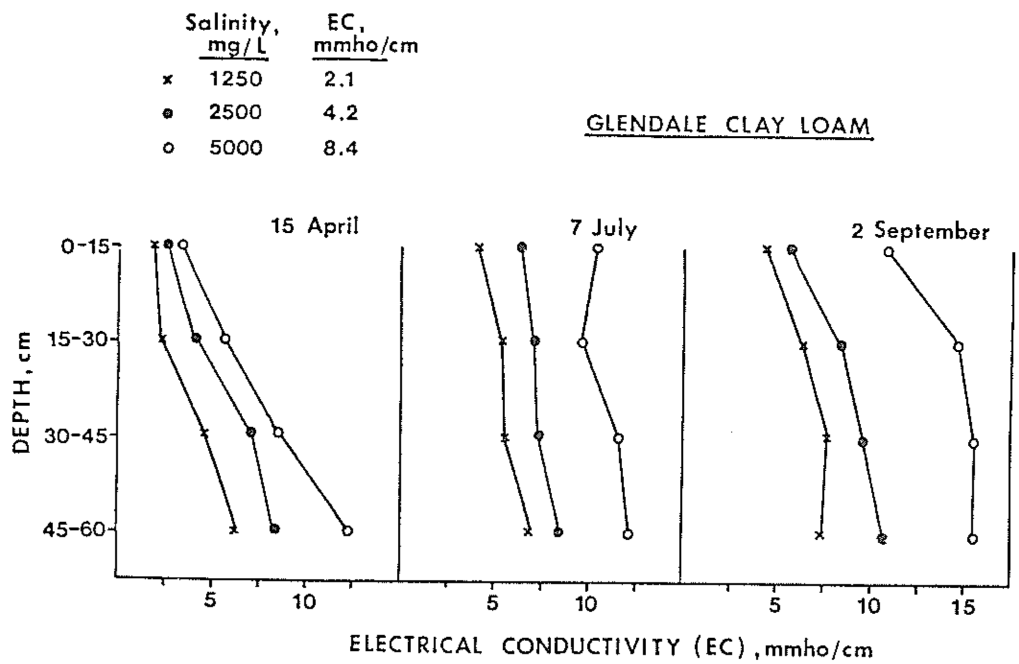

Fig. 8. Electrical conductivity at four depths in soil profile with three levels of salinity on three dates, Glendale clay loam soil, 1983.

shown in Tables 5, 6, and 7 for 1981, 1982, and 1983, respectively. The associated analyses of variance are shown in Appendix Tables 11, 12, and 13.

Calcium percentages were generally below the normal range of 0.4 to 1.0 % (McDonald et al., 1973). A significant effect of salinity treatment was observed only at the first harvest in 1983, when a linear effect was observed (Appendix Table 11). Magnesium percentage, on the other hand, was consistently affected by salinity treatment, except at the 1981 harvest. Both linear and quadratic effects were observed in the other four harvests (Appendix Tables 12 and 13). Magnesium percentages were generally in the low range (below 0.1 %) or at the low end of the normal range for grasses (0.12 to 0.25 %). Potassium percentages were in the normal range (1.2 to 2.8 %) and were not affected by salinity treatment, except at the second harvest in 1983. In this harvest, potassium percentage decreased with increasing levels of salinity. Sodium percentage significantly increased with increasing salinity in three of the five harvests. In the other two harvests, similar trends were observed, but they were not significant. Sodium percentages were generally very high. Phosphorus percentages were generally low (below 0.2 %) and, although differences were significant at the 1981 harvest and at the second harvest in 1982, the differences were small.

Crude protein percentages were generally relatively high except at the first harvest in 1982. Significant differences were observed at this harvest, but not at the other four harvests.

Dry forage yield was affected at three of the five harvests. In each case, yields at 1,250 mg/L were lower than yields at 2,500 mg/L, and generally there was then a decrease in yields with further increases in

Table 5. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 21 August, 1981.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------				-%			kg/ha
1,250	0.34	0.14	1.75	0.22	0.22	15.5	1499
2,500	0.34	0.14	1.54	0.38	0.20	14.5	1548
5,000	0.39	0.14	1.72	0.55	0.20	16.5	1576
10,000	0.44	0.12	1.53	0.78	0.19	13.6	1311
Mean	0.38	0.13	1.63	0.49	0.20	15.8	1484
	ns	ns	ns	**	*	ns	ns
C.V.%	13.43	9.81	13.42	16.39	5.71	9.88	18.86

ns = non-significant
*, **= significant at 5% and 1% levels of probability, respectively.

Table 6. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 10 August and 16 October, 1982.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------				%			kg/ha
Harvest 1 (10 August)							
1,250	0.37	0.10	1.83	0.68	0.16	7.3	2955
2,500	0.33	0.08	1.69	0.80	0.13	10.3	3537
5,000	0.35	0.06	1.52	0.91	0.15	9.8	2783
10,000	0.33	0.05	1.51	0.98	0.15	8.6	1910
Mean	0.34	0.07	1.64	0.84	0.15	9.0	2796
	ns	**	ns	ns	ns	*	**
C.V.%	19.07	6.89	10.49	17.17	11.89	13.46	13.36
Harvest 2 (16 October)							
1,250	0.48	0.11	1.34	0.97	0.16	10.7	759
2,500	0.44	0.08	1.15	1.12	0.14	11.7	858
5,000	0.44	0.08	1.31	1.51	0.15	11.9	734
10,000	0.40	0.07	1.38	1.58	0.15	12.4	535
Mean	0.44	0.08	1.30	1.29	0.15	11.7	721
	ns	**	ns	*	*	ns	**
C.V.%	12.11	12.81	16.20	17.89	5.61	7.08	7.95

ns = non-significant
*, ** = significant at 5% and 1% levels of probability, respectively.

Table 7. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 30 June and 24 August, 1983.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
-------mg/L-------				%			kg/ha
Harvest 1 (30 June)							
1,250	0.30	0.13	2.08	0.63	0.20	14.4	2285
2,500	0.25	0.10	1.88	1.15	0.18	15.1	3155
5,000	0.33	0.08	2.00	1.53	0.20	13.6	2305
10,000	0.34	0.06	1.98	1.55	0.21	15.4	1600
Mean	0.31	0.09	1.99	1.22	0.20	14.6	2336
	**	**	ns	**	*	ns	**
C.V.%	9.21	9.19	10.54	20.08	6.43	13.09	16.10
Harvest 2 (24 August)							
1,250	0.26	0.12	1.96	0.56	0.21	14.6	1175
2,500	0.31	0.09	1.72	0.68	0.19	14.9	2195
5,000	0.31	0.07	1.58	0.73	0.19	15.1	2435
10,000	0.30	0.05	1.56	0.79	0.21	15.5	1550
Mean	0.30	0.08	1.67	0.71	0.20	15.1	1839
	ns	**	*	ns	ns	ns	ns
C.V.%	11.72	13.05	6.95	18.46	6.89	12.73	41.21

ns = non-significant.
*, ** = significant at 5% and 1% levels of probability, respectively.

salinity. The lower yields at 1,250 mg/L may not have been a direct function of the lower salinity, however, but rather an indirect function of competition from weeds. Infestation with bermudagrass (Cynodon dactylon) was a problem, particularly at the lower salinities, although spot treatments of glyphosate were used to control it in 1981 and 1982. In 1983, bermudagrass and other weeds were not controlled to determine the effects of weed competition. Table 8 shows the percentage of the plots that were infested with bermudagrass on three dates in 1983. In addition, the percentages of other weeds in the areas not infested with bermudagrass were estimated on 7 September and are also shown in Table 8. Although weed percentages varied tremendously at each salinity, as can be observed from the high coefficients of variation (CV), there was a clear reduction in weed competition with increasing salinity. At 5,000 mg/L, only one plot was severely infested with bermudagrass, and no weeds were present at 10,000 mg/L. At 1,250 mg/L, weeds were a severe problem and may have resulted in lower yields in these plots. The dry forage yields shown are saltgrass with weeds removed. Major weed problems other than bermudagrass were white horsenettle (Solanum elaeagnifolium), nutsedge (Cyperus spp.), barnyardgrass (Echinochloa crus-galli), junglerice (Echinochloa colonum), Lehman's lovegrass (Eragrostis lehmanniana), feather fingergrass (Chloris virgata), and scratchgrass (Muhlenbergia asperifolia).

Three harvests were taken at the post-anthesis stage for the sandy loam soil. In 1982, the plots did not reach this stage again after the first cut on 23 August. In 1983, two harvests were taken, on 13 July and 7 September. Mineral percentages, crude protein percentages, and dry forage yields for each salinity level are shown in Tables 9 and 10, respectively. The associated analyses of variance are shown in Appendix Tables 14 and 15.

Table 8. Mean percentage of bermudagrass and other weeds in saltgrass with four levels of salinity, Brazito sandy loam soil, 1983.

	26 May	11 July	7 September	
Salinity	% bermudagrass	% bermudagrass	% bermudagrass	% other weeds
--mg/L--	----------------	--------------- %	---------------	----------------
1,250	50.0	53.7	67.5	49.2
2,500	17.5	16.2	21.2	46.2
5,000	15.0	16.2	21.2	2.2
10,000	0.0	0.0	0.0	0.0
Mean	20.6	21.6	27.5	24.4
$LSD_{0.05}$	40.2	38.8	60.8	48.1
C.V.%	126.5	116.8	143.5	127.8

Table 9. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with four levels of salinity, Brazito sandy loam soil, 23 August, 1982.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L-----				%			kg/ha
1,250	0.37	0.11	1.74	0.80	0.16	13.2	3180
2,500	0.35	0.09	1.68	0.75	0.17	13.2	3497
5,000	0.32	0.07	1.32	0.87	0.15	14.1	2487
10,000	0.31	0.06	1.40	0.98	0.16	13.7	2428
Mean	0.34	0.08	1.52	0.86	0.16	13.5	2898
	ns	**	*	ns	ns	ns	*
C.V.%	17.94	5.67	10.25	31.27	16.78	8.55	17.46

ns = non-significant

*, ** = significant at 5% and 1% levels of probability, respectively.

Table 10. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with four levels of salinity, Brazito sandy loam soil, 13 July and 7 September, 1983.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
-------mg/L------	----------	----------	----------	%	----------	----------	kg/ha
Harvest 1 (13 July)							
1,250	0.34	0.09	1.66	0.54	0.17	12.1	2100
2,500	0.29	0.07	1.46	0.93	0.14	13.8	3540
5,000	0.35	0.06	1.56	1.33	0.15	13.8	2850
10,000	0.39	0.05	1.53	1.40	0.16	14.1	2170
Mean	0.34	0.07	1.55	1.08	0.16	13.5	2665
	ns	ns	ns	**	**	ns	*
C.V.%	13.19	24.71	6.46	20.42	5.13	13.00	22.41
Harvest 2 (7 September)							
1,250	0.32	0.12	2.02	0.66	0.19	13.2	540
2,500	0.26	0.08	1.68	0.92	0.17	13.3	1940
5,000	0.28	0.09	1.36	1.44	0.18	13.1	1490
10,000	0.31	0.07	1.73	1.48	0.20	14.1	1795
Mean	0.29	0.08	1.64	1.24	0.18	13.5	1441
	ns	ns	ns	**	ns	ns	ns
C.V. %	9.55	36.92	15.95	11.42	13.81	11.63	76.35

ns = non-significant
*, ** = significant at 5% and 1% levels of probability, respectively.

Similar results were observed at the post-anthesis stage as at the anthesis stage. Calcium percentages were not affected by salinity treatment and were similar to values at the anthesis stage. Magnesium percentages were again relatively low and generally declined with increasing salinity. This effect was significant only at the 1982 harvest, however. Potassium percentages were also significantly reduced with increasing salinity in the 1982 harvest but not in the 1983 harvests. Sodium percentages significantly increased with increasing salinity in the two 1983 harvests, and although there appeared to be a similar trend in the 1982 harvest, this was not significant. Phosphorus percentages were significantly affected by salinity treatment at the first harvest, 1983, but differences were not large and no significant differences were observed in the other two harvests. Crude protein percentages were not affected.

Dry forage yields were generally lower at 1,250 mg/L than at 2,500 mg/L, as was also observed at the anthesis stage. Again, this difference could be attributed to competition from weeds rather than direct effect of salinity (see Table 8). Above 2,500 mg/L, yields appeared to be reduced by increasing salinity.

Differences in mineral percentages at the anthesis and post-anthesis stages were small. Crude protein percentages were lower at the post-anthesis stage than at the anthesis stage at the 1983 harvests as would be expected by the increased maturity of the harvested forage at the post-anthesis stage, but this was not true at the 1982 harvest. Total dry forage yields at the anthesis stage were higher than at the post-anthesis stage in 1982, primarily due to the fact that two harvests could be taken at anthesis, but only one at the post-anthesis stage (Table 11). In 1983, differences were less, but again the mean total dry forage yield was higher

Table 11. Total dry forage yield of saltgrass at the anthesis stage and at the post-anthesis stage with four levels of salinity, Brazito sandy loam soil, 1982 and 1983.

Salinity	1982		1983	
	Anthesis	Post-anthesis	Anthesis	Post-anthesis
--mg/L--	----------kg/ha----------			
1,250	3714	3180	3460	2640
2,500	4395	3497	5350	5480
5,000	3517	2487	4740	4340
10,000	2445	2428	3150	3965
Mean	3518	2898	4175	4106
	**	*	*	*
C.V.%	11.58	17.46	22.17	26.79

*, ** = significant at the 5% and 1% levels of probability, respectively.

at the anthesis stage than at the post-anthesis stage. Significant differences in total dry forage yield were observed with yields lower at 1,250 mg/L than at 2,500 mg/L. Above 2,500 mg/L, yields decreased with increasing salinity.

Forage quality and yield--Glendale clay loam soil. Five harvests were taken at anthesis for the clay loam soil. Three were taken in 1982 and two in 1983. Mineral percentages, crude protein percentages, and dry forage yields for each salinity level are shown in Tables 12 and 13 for 1982 and 1983, respectively. The analyses of variance are shown in Appendix Tables 16 and 17.

Five harvests were also taken at the post-anthesis stage for the clay loam soil, three in 1982 and two in 1983. Mineral percentages, crude protein percentages, and dry forage yields for each salinity level are shown in Tables 14 and 15 for 1982 and 1983, respectively, and the associated analyses of variance are shown in Appendix Tables 18 and 19.

There were few significant effects of the salinity treatments at either the anthesis or post-anthesis stage, and there were few consistent trends. The lack of significant differences was presumably due to the lesser salinization of the clay loam soil than was found for the sandy loam soil. However, in 1983, plant sodium percentages generally increased with greater salinity, although no significant differences were observed. Salinization was greater in 1983 than in 1982 and this would account for the trend for increasing sodium percentages in 1983.

In a comparison between saltgrass harvested at the anthesis stage and at the post-anthesis stage, there were few differences in mineral percentages. However, with the exception of the third harvest in 1982, crude

Table 12. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with three levels of salinity, Glendale clay loam soil, 14 May, 23 June, and 11 August, 1982.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------	----------------------			%		-----------------------	kg/ha
Harvest 1 (14 May)							
1,250	0.44	0.11	1.77	1.01	0.15	15.8	1668
2,500	0.46	0.09	1.92	1.11	0.17	15.4	1981
5,000	0.48	0.10	1.72	1.13	0.15	15.7	1535
Mean	0.46	0.10	1.80	1.08	0.16	15.6	1728
	ns	ns	ns	ns	ns	ns	ns
C.V.%	6.58	27.64	6.98	11.86	6.55	7.39	38.60
Harvest 2 (23 June)							
1,250	0.47	0.16	1.64	1.26	0.18	13.7	2859
2,500	0.43	0.16	1.68	1.17	0.19	13.5	3681
5,000	0.50	0.15	1.77	1.29	0.14	13.3	3373
Mean	0.47	0.16	1.70	1.24	0.18	13.5	3304
	ns	ns	**	ns	ns	ns	ns
C.V.%	8.57	8.62	9.33	13.59	5.40	5.37	18.02
Harvest 3 (11 August)							
1,250	0.50	0.15	1.55	1.16	0.18	12.9	2885
2,500	0.44	0.16	1.67	1.15	0.19	13.0	3755
5,000	0.55	0.14	1.68	1.20	0.19	12.7	3612
Mean	0.50	0.15	1.63	1.17	0.19	12.9	3418
	ns	ns	ns	ns	ns	ns	ns
C.V.%	12.57	10.57	13.26	11.79	6.05	6.41	14.96

ns = non-significant
** = significant at 1% level of probability

Table 13. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with three levels of salinity, Glendale clay loam soil, 27 June and 26 August, 1983.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------				%			kg/ha
Harvest 1 (27 June)							
1,250	0.47	0.13	1.95	1.75	0.20	16.9	2450
2,500	0.61	0.13	1.94	2.14	0.19	14.6	1910
5,000	0.55	0.13	2.04	2.37	0.20	18.1	1975
Mean	0.54	0.13	1.97	2.09	0.20	16.5	2112
	*	ns	ns	ns	ns	ns	ns
C.V.%	9.76	9.66	14.24	20.07	7.55	15.15	27.18
Harvest 2 (26 August)							
1,250	0.20	0.10	1.51	0.23	0.13	9.5	2670
2,500	0.29	0.10	1.30	0.22	0.14	8.1	1830
5,000	0.27	0.09	1.61	0.30	0.13	8.5	3837
Mean	0.26	0.09	1.49	0.26	0.13	8.6	2779
	ns	ns	*	ns	ns	ns	ns
C.V.%	11.75	1.86	2.18	17.39	4.97	9.19	109.9

ns = non-significant
* = significant at 5% level of probability.

Table 14. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with three levels of salinity, Glendale clay loam soil, 21 May, 6 July, and 15 September, 1982.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------	--------------------			%		---------------------	kg/ha
Harvest 1 (21 May)							
1,250	0.43	0.11	2.02	1.09	0.15	14.5	2208
2,500	0.50	0.11	1.84	1.29	0.15	14.0	1568
5,000	0.57	0.12	1.85	1.51	0.14	14.6	2028
Mean	0.50	0.11	1.90	1.29	0.14	14.4	1934
	ns	ns	ns	ns	ns	ns	ns
C.V.%	11.88	10.99	6.48	14.92	9.11	8.49	38.88
Harvest 2 (6 July)							
1,250	0.48	0.15	1.65	0.92	0.15	13.4	5190
2,500	0.41	0.14	1.72	0.89	0.16	13.2	3927
5,000	0.44	0.15	1.87	0.96	0.14	12.9	5220
Mean	0.44	0.15	1.74	0.92	0.15	13.2	4779
	ns	ns	ns	ns	ns	ns	ns
C.V.%	13.42	19.08	15.10	16.40	6.34	7.26	15.31
Harvest 3 (15 September)							
1,250	0.22	0.11	1.53	0.76	0.16	16.2	2360
2,500	0.21	0.10	1.36	0.71	0.15	15.1	2450
5,000	0.22	0.10	1.31	0.81	0.16	15.0	2047
Mean	0.21	0.10	1.41	0.76	0.16	15.5	2286
	ns	ns	ns	ns	ns	ns	ns
C.V.%	22.96	12.27	10.60	27.54	11.15	4.46	12.37

ns = non-significant

Table 15. Mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with three levels of salinity, Glendale clay loam soil, 13 July and 12 September, 1983.

Salinity	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
------mg/L------	%						kg/ha
Harvest 1 (13 July)							
1,250	0.40	0.10	1.66	1.75	0.19	11.8	4850
2,500	0.37	0.08	1.58	2.14	0.16	10.0	3960
5,000	0.41	0.09	1.80	2.37	0.20	13.1	3485
Mean	0.39	0.09	1.68	2.09	0.18	11.6	4098
	ns	**	ns	ns	**	ns	ns
C.V.%	20.40	6.77	10.93	20.07	4.75	16.12	43.28
Harvest 2 (12 September)							
1,250	0.30	0.12	0.63	0.55	0.10	6.8	1550
2,500	0.37	0.11	0.86	0.75	0.11	5.7	1402
5,000	0.34	0.08	0.84	1.10	0.10	6.0	1355
Mean	0.34	0.10	0.78	0.80	0.10	6.2	1436
	ns	ns	ns	ns	ns	ns	ns
C.V.%	36.66	8.73	10.72	7.44	12.13	9.74	96.76

ns = non-significant
** = significant at 1% level of probability

protein percentages were higher at the anthesis stage than at the post-anthesis stage. This would be expected since protein percentages tend to decline with increasing maturity of the forage. Total dry forage yields for 1982 and 1983 at the anthesis and post-anthesis stages are shown in Table 16. In the clay loam soil, unlike in the sandy loam soil, yields at the post-anthesis stage were higher than at the anthesis stage, but were not affected by the salinity treatment. There was considerable variation in saltgrass yield among plots within the same treatment as can be observed by the high CV%. The main reason for this was the large variation in weed population, which consisted primarily of bermudagrass (*Cynodon dactylon*), barnyard grass (*Echinochloa crus-galli*) and jungle rice (*Echinochloa colonum*). Weeds were controlled during 1981 and 1982 but, in 1983, weeds were not controlled to determine the effects of weed competition. The percentages of bermudagrass in the plots are shown in Table 17 for each salinity level. There was no significant difference among salinity treatments, but there was considerable variation within treatments as observed by the high CV%.

Digestibility. The *in vitro* dry matter digestibility of saltgrass for three harvests is shown in Table 18. Material from one harvest for the sandy loam soil and from two harvests for the clay loam soil was analyzed.

No significant effects of the salinity treatments were observed at any of the three harvests. Mean digestibility for the sandy loam soil was 37.4 %, and was 51.3 and 48.1 % at the two harvests for the clay loam soil. Digestibility for the sandy loam soil was determined at the post-anthesis stage, while it was determined at the anthesis stage for the clay loam soil. This difference may partly explain the lower digestbility in the sandy loam soil. In addition, the apparent lower fertility of the sandy loam soil may have affected the digestibility of the saltgrass.

Table 16. Total dry forage yield of saltgrass at the anthesis stage and at the post-anthesis stage at three levels of salinity, Glendale clay loam soil, 1982 and 1983.

Salinity	1982		1983	
	Anthesis	Post-anthesis	Anthesis	Post-anthesis
--mg/L--	--------------------------kg/ha	----------------------------		
1,250	7412	9758	5120	6400
2,500	9417	7945	3740	5362
5,000	8520	9295	5812	4840
Mean	8450	8999	4891	5534
	ns	ns	ns	ns
C.V.%	14.44	15.44	69.12	49.03

ns = non-significant

Table 17. Mean percentage of bermudagrass in saltgrass with three levels of salinity, Glendale clay loam, 1983.

Salinity		26 May	11 July	7 September
--mg/L--		-------------% bermudagrass	-----------------	
1,250		31.2	43.7	62.5
2,500		26.2	35.0	45.0
5,000		31.2	40.0	57.5
	Mean	29.2	39.6	55.0
	$LSD_{0.05}$	ns	ns	ns
	C.V.%	79.2	74.7	68.7

ns = non-significant

Table 18. *In vitro* dry matter digestibility of saltgrass with four levels of salinity, Brazito sandy loam soil, 23 August, 1982, and with three levels of salinity, Glendale clay loam soil, 14 May and 23 June, 1982.

Salinity	Brazito sandy loam	Glendale clay loam	
	23 August, 1982	14 May, 1982	23 June, 1982
--mg/L--	--------------	--%--	--------------
1,250	36.5	52.3	48.2
2,500	37.3	50.8	49.2
5,000	36.0	50.8	47.4
10,000	39.8	--	--
Mean	37.4	51.3	48.1
	ns	ns	ns

ns = non-significant

Comparison between soils. In general, the mineral percentages found in saltgrass grown in the clay loam soil were higher than those found in saltgrass grown in the sandy loam soils, with the exception of potassium and phosphorus percentages. Mean mineral percentages for each growth stage are shown for each soil in Table 19. Calcium, magnesium, and sodium percentages were higher for the clay loam soil than for the sandy loam soil at the same growth stage. Potassium percentages were similar, and phosphorus percentages were slightly higher for the sandy loam soil.

Total dry forage yields were much higher in the clay loam soil than in the sandy loam soil. The higher fertility and water-holding capacity of the clay loam soil are probably the main reasons for this difference.

Table 19. Mean mineral percentages, crude protein percentages, and dry forage yields of saltgrass at the anthesis stage and at the post-anthesis stage for two soil types.

Soil type	Growth stage	Ca	Mg	K	Na	P	Crude protein	Total dry forage yield
		%						kg/ha
Clay loam	Anthesis	0.45	0.13	1.72	1.17	0.17	13.4	6670
	Post-anthesis	0.38	0.11	1.50	1.17	0.15	12.2	7266
Sandy loam	Anthesis	0.35	0.09	1.65	0.91	0.18	13.2	3846
	Post-anthesis	0.32	0.08	1.57	1.06	0.17	13.5	3502
Mean		0.37	0.10	1.61	1.08	0.17	13.1	5321

DISCUSSION AND CONCLUSIONS

Saltgrass was planted by sprigging in two soils, a sandy loam and a clay loam soil. In the dandy loam soil, water containing 1,250, 2,500, 5,000, and 10,000 mg/L TDS was applied and, in the clay loam soil, water containing 1,250, 2,500, and 5,000 mg/L TDS was applied.

The sandy loam soil was more highly salinized than the clay loam soil, based on measurements of sodium adsorption ratio and electrical conductivity. In the sandy loam soil, yields were relatively low, with a mean total dry forage yield of 3,674 kg/ha. Highest yields were achieved at 2,500 mg/L, with increasing salinity leading to decreased yields. Yields at 1,250 mg/L were lower than at 2,500 mg/L, primarily due to heavy competition from weeds. Sodium percentage in the tissue generally increased with increasing salinity, as has also been observed for bermudagrass (Dudeck et al., 1983). As saltgrass tends to accumulate sodium this result was not unexpected. Magnesium percentage generally decreased with increasing salinity presumably due to competitive inhibition of magnesium uptake by sodium. With bermudagrass, Dudeck *et al*. (1983) found that potassium percentage decreased with increasing salinity but, except at two harvests, this was not observed consistently in this study. Calcium, phosphorus, and crude protein percentages, and *in vitro* dry matter digestibility were generally not affected by increasing salinity.

The clay loam soil was not completely salinized during the course of the experiment, partly because of the greater buffering capacity of the soil, and partly because lower amounts of water were applied due to the greater water-holding capacity of this soil. Accordingly, the salinity treatments did not affect the dry forage yields, mineral percentages, crude protein percentages, or *in vitro* dry matter digestibility.

In the clay loam soil, dry forage yields were relatively high, with a mean total yield of 6,968 kg/ha.

Overall, calcium, magnesium and phosphorus percentages were generally low or at the low end of the normal range for grasses (McDonald et al., 1973). However, calcium and phosphorus percentages were similar to those observed for another warm-season C-4 grass in this area, kleingrass (Penaranda, 1982; Clark and Lugg, 1985). Magnesium was lower than was observed for kleingrass. Calcium to phosphorus ratios were generally close to the suggested optimal ratio of 2:1. Potassium percentages were in the normal range for grasses (McDonald et al., 1973). Crude protein percentages were relatively high for warm-season grasses, and was higher than usual for warm-season grasses such as bermudagrass in this area (Lugg and Watson, 1983). Sodium percentage was very high, with mean percentages ranging from 0.22 to 2.37%. A normal value is 0.13% (Walton, 1983). However, when beef cattle were fed high grain diets containing up to 7% NaCl, no negative effects were observed up to levels of 5% (Croom et al., 1982). In fact, a more efficient utilization of protein was observed in sheep with high sodium levels in the diet (Hemsley et al., 1975). Water intake was shown to increase with increasing sodium content in the diet for both beef cattle (Croom et al., 1982) and sheep (Hemsley et al., 1975). Considerable variation was observed in sodium percentages, due primarily to the incidence of rainfall. Saltgrass extrudes salt through salt glands (Hansen et al., 1976) and rainfall, therefore, tends to wash salt from the surface of the leaves and stems. Saltgrass grown in the clay soils was generally higher in calcium, magnesium, and sodium percentages, similar in potassium and crude protein percentages, and lower in phosphorus percentage than saltgrass grown in sandy loam soils.

From the mean mineral and crude protein percentages shown in Table 19, the amounts of minerals and digestible crude protein supplied by saltgrass were calculated. Digestible crude protein was calculated using the following formula (McDonald et al., 1973):

$$DCP = (CP \times 0.9115) - 3.67$$

where DCP = Digestible Crude Protein %, and CP = Crude Protein %. In Table 20, the amounts supplied by the saltgrass are compared with the amounts required by 400 kg and 250 kg steers gaining at the rate of 0.5 kg/day. Amounts required were taken from McDonald et al. (1973). The amounts supplied were calculated based on the assumption that each animal was consuming 2 % of its body weight each day. In general, the amounts of calcium, magnesium and digestible crude protein supplied meet the requirements of the steers. The amounts of sodium supplied far exceed the daily requirements. Phosphorus is the only mineral that is not supplied in the required amounts. In this area, forages are frequently low in phosphorus, and phosphorus is often added to animal rations as dicalcium phosphate.

Digestibility of the saltgrass was relatively low, especially in the sandy loam soil, where mean digestibility was 37.4 %. In the clay loam soil, mean digestibility was 49.7 %, similar to that observed for another warm-season C-4 grass in this area, kleingrass (Penaranda, 1982; Clark and Lugg, 1985). The relatively low digestibilities may restrict intake by grazing animals, thus lowering the amounts of mineral nutrients supplied. The low digestibilities commonly found in C-4 grasses are thought to be due to the high proportion of vascular tissue and the resistance of bundle sheath cells to microbial breakdown in the rumen (Wilson et al., 1983).

Table 20. Minerals and digestible crude protein supplied by saltgrass based on intake of 2% of body weight per day compared with amounts required by a 400 kg steer and by a 250 kg steer gaining at the rate of 0.5 kg/day.

Animal		Ca	Mg	Na	P	Digestible crude protein
		g/day				
400 kg steer (rate of gain = 0.5 kg/day)	Required	26.0	7.0	7.5	24.0	440.0
	Supplied†	29.6	8.0	86.4	13.6	661.6
250 kg steer (rate of gain = 0.5 kg/day)	Required	20.0	4.8	5.0	13.0	400.0
	Supplied†	18.5	5.0	54.0	8.5	413.5

†Based on intake of 2% of body weight per day.

Overall, it can be concluded that saltgrass has the potential to be used as a pasture grass when irrigated with saline water. At 1,250 and 2,500 mg/L TDS, there are better forages available, and saltgrass could not compete well with weeds. However, at 5,000 and 10,000 mg/L TDS, saltgrass produces adequate amounts of forage of reasonable quality, and there are few other forages available for use at these salinities. At 10,000 mg/L, although yields were reasonable, the saltgrass appeared stunted and was a very dark green; this salinity may be higher than the level practical for saltgrass production.

Further studies need to be done before saltgrass can be considered as a practical possibility. Firstly, it is necessary to conduct animal feeding trials to determine forage intake, forage palatability, and animal performance. Secondly, although successful stand establishment was accomplished by sprigging, it was not a convenient method of planting, and the possibilities of saltgrass seed production need to be explored.

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A P P E N D I X

Appendix Table 1. Analyses of variance for mineral percentages, crube protein percentage, and dry forage yield of saltgrass grown in the greenhouse with four levels of salinity, Brazito sandy loam soil, 4 August and 30 September, 1981.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Harvest 1 (4 August)								
Block	3	0.69	2.73	2.85	0.03	0.15	1.69	0.27
Salinity	3	0.47	9.16**	1.52	0.56	0.57	6.71*	1.37
Linear	1	1.21	24.31**	0.02	0.29	1.40	17.45**	0.27
Quadratic	1	0.11	1.14	3.63	1.14	0.26	2.15	0.24
Error mean square		7.358×10^{-3}	8.878×10^{-5}	3.505×10^{-5}	6.748×10^{-2}	7.671×10^{-2}	5.530×10^{-1}	6.337×10^{4}
Error degrees of freedom		5	7	8	8	8	9	9
Harvest 2 (30 September)								
Block	3	0.21	0.32	1.79	1.33	0.57	1.40	1.05
Salinity	3	1.64	0.45	1.34	1.53	2.33	2.72	10.28**
Linear	1	0.03	0.88	1.76	1.07	1.09	0.02	22.70**
Quadratic	1	3.81	0.10	0.13	2.74	5.89*	6.55*	7.18*
Error mean square		3.113×10^{-2}	5.897×10^{-4}	2.814×10^{-2}	7.755×10^{-2}	2.674×10^{-4}	5.026×10^{-1}	5.990×10^{-3}
Error degrees of freedom		5	7	7	6	9	9	9

*, ** = significant at 5% and 1% levels of probability, respectively.

Appendix Table 2. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass grown in the greenhouse with four levels of salinity, Glendale clay laom soil, 4 August and 30 September, 1981.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		--------	--------	--------	F values	--------	--------	--------
Harvest 1 (4 August)								
Block	3	2.10	1.24	1.94	0.63	1.70	2.33	0.39
Salinity	3	1.89	0.53	10.10**	6.99**	0.56	0.50	1.50
Linear	1	5.57	0.07	22.34**	4.33	1.03	0.62	0.24
Quadratic	1	0.03	1.49	5.30*	15.20**	0.42	0.87	0.04
Error mean square		8.550×10^{-3}	1.370×10^{-3}	1.083×10^{-1}	2.172×10^{-2}	8.892×10^{-5}	8.593×10^{-1}	1.192×10^{4}
Error degrees of freedom		7	8	9	9	9	9	9
Harvest 2 (30 September)								
Block	3	0.97	0.64	0.38	0.77	1.20	9.16**	2.99
Salinity	3	0.48	0.64	0.72	3.83	1.43	3.83	5.70*
Linear	1	0.73	0.07	0.97	2.73	0.75	1.83	16.81**
Quadratic	1	0.40	1.73	1.24	5.00	1.72	5.16	0.00
Error mean square		1.498×10^{-2}	1.132×10^{-3}	2.843×10^{-4}	2.330×10^{-2}	3.012×10^{-2}	2.609×10^{-1}	2.998×10^{4}
Error degrees of freedom		6	7	7	7	7	7	9

*, ** = significant at 5% and 1% levels of probability, respectively.

Appendix Table 3. Sodium adsorption ratio in top 15 cm of soil profile with four levels of salinity, Brazito sandy loam soil.

Date	Salinity, mg/L			
	1,250	2,500	5,000	10,000
	---SAR---			
26 March, 1981	1.54	1.54	1.54	1.54
6 April, 1982	18.65	38.85	49.95	82.18
30 June, 1982	17.29	21.13	41.23	60.98
19 August, 1982	12.07	15.74	---†	71.31
19 October, 1982	15.86	15.77	24.80	44.30
11 April, 1983	9.61	20.93	22.14	41.58
6 July, 1983	18.65	21.05	22.40	32.30
24 August, 1983	21.10	24.98	44.62	43.37
Mean (excluding March, 1981)	16.18	22.64	34.19	53.72

†missing data

Appendix Table 4. Electrical conductivity in top 15 cm of soil profile with four levels of salinity, Brazito sandy loam soil.

Date	Salinity, mg/L			
	1,250	2,500	5,000	10,000
	---mmho/cm---			
26 March, 1981	2.00	2.00	2.00	2.00
6 April, 1982	2.78	9.45	11.18	26.17
30 June, 1982	4.50	6.55	10.34	16.00
19 August, 1982	2.42	7.14	11.69	19.38
19 October, 1982	3.14	2.92	5.40	9.99
11 April, 1983	1.49	2.59	3.88	6.84
6 July, 1983	3.31	6.38	6.39	14.26
24 August, 1983	6.75	6.65	10.04	13.99
Mean (excluding March, 1981)	3.48	4.72	8.42	15.23

Appendix Table 5. Sodium adsorption ratio (SAR) at four depths in the soil profile with four levels of salinity, Brazito sandy loam soil.

Date	Depth	Salinity, mg/L			
		1,250	2,500	5,000	10,000
	--cm--	SAR			
11 April, 1983	0-15	9.61	20.93	22.14	41.58
	15-30	13.39	28.96	34.14	51.31
	30-45	11.71	16.62	32.10	47.39
	45-60	8.05	16.39	18.76	40.04
6 July, 1983	0-15	18.65	21.05	22.40	32.30
	15-30	20.20	30.85	32.90	47.40
	30-45	15.65	24.25	33.80	50.25
	45-60	10.05	26.70	32.00	46.45
24 August, 1983	0-15	21.10	24.98	44.62	43.37
	15-30	21.47	42.06	48.00	57.74
	30-45	14.36	44.52	45.02	67.74
	45-60	9.63	9.40	48.41	49.71
Mean		14.48	25.56	34.52	47.94

Appendix Table 6. Electrical conductivity at four depths in the soil profile with four levels of salinity, Brazito sandy loam soil.

Date	Depth	Salinity, mg/L			
		1,250	2,500	5,000	10,000
	--cm--	mmho/cm			
11 April, 1983	0-15	1.49	2.59	3.88	6.84
	15-30	3.43	7.66	9.21	16.94
	30-45	7.42	7.56	11.73	25.20
	45-60	6.48	8.46	15.89	11.58
6 July, 1983	0-15	3.31	6.38	6.39	14.26
	15-30	8.92	7.87	14.76	24.07
	30-45	9.66	7.91	14.21	22.20
	45-60	3.12	7.03	12.14	11.26
24 August, 1983	0-15	6.75	6.65	10.04	13.99
	15-30	9.31	15.49	19.33	18.59
	30-45	6.02	19.65	20.29	23.50
	45-60	1.58	5.38	28.41	11.75
Mean		5.62	8.55	13.86	16.68

Appendix Table 7. Sodium adsorption ratio in top 15 cm of soil profile with three levels of salinity, Glendale clay loam soil.

Date	Salinity, mg/L		
	1,250	2,500	5,000
	SAR		
26 March, 1981	3.17	3.17	3.17
14 April, 1982	7.81	10.01	10.72
19 August, 1982	10.19	14.45	16.96
19 October, 1982	11.58	13.17	24.55
15 April, 1983	8.53	9.17	17.24
2 July, 1983	10.60	17.70	21.25
2 September, 1983	13.07	18.23	24.71
Mean (excluding March, 1981)	10.30	13.79	19.24

Appendix Table 8. Electrical conductivity in top 15 cm of soil profile with three levels of salinity, Glendale clay loam soil.

Date	Salinity, mg/L		
	1,250	2,500	5,000
	mmho/cm		
26 March, 1981	3.00	3.00	3.00
14 April, 1982	2.71	3.11	4.31
19 August, 1982	4.44	4.47	8.22
19 October, 1982	3.72	4.42	5.43
15 April, 1983	1.86	2.51	3.34
7 July, 1983	4.09	6.37	10.36
2 September, 1983	4.29	5.71	10.69
Mean (excluding March, 1981)	3.52	4.43	7.06

Appendix Table 9. Sodium adsorption ratio (SAR) at four depths in the soil profile with three levels of salinity, Glendale clay loam soil.

Date	Depth	Salinity, mg/L		
		1,250	2,500	5,000
	--cm--	SAR		
15 April, 1983	0-15	8.53	9.17	17.24
	15-30	7.49	8.15	11.35
	30-45	6.56	7.78	9.48
	45-60	5.00	5.37	7.24
7 July, 1983	0-15	10.60	17.70	21.25
	15-30	9.75	11.30	14.30
	30-45	6.70	9.80	10.28
	45-60	6.20	8.40	9.75
2 September, 1983	0-15	13.07	18.23	24.71
	15-30	9.17	11.93	14.51
	30-45	7.93	9.09	11.52
	45-60	7.45	8.78	9.62
Mean		8.20	10.47	13.44

Appendix Table 10. Electrical conductivity at four depths in the soil profile with three levels of salinity, Glendale clay loam soil.

Date	Depth	Salinity, mg/L		
		1,250	2,500	5,000
	--cm--	----------mmho/cm----------		
15 April, 1983	0-15	1.86	2.51	3.34
	15-30	2.44	4.05	5.71
	30-45	4.77	7.15	8.61
	45-60	6.37	8.34	12.23
7 July, 1983	0-15	4.09	6.37	10.37
	15-30	5.41	7.02	9.60
	30-45	5.57	7.36	11.64
	45-60	6.97	8.42	12.12
2 September, 1983	0-15	4.29	5.71	10.69
	15-30	6.46	8.38	14.79
	30-45	7.82	9.63	15.59
	45-60	7.38	10.70	15.65
Mean		5.29	7.14	10.86

Appendix Table 11. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 21 August, 1981.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Block	3	0.36	0.80	0.70	1.08	5.95*	0.14	1.72
Salinity	3	3.25	1.81	1.15	35.69**	4.72*	1.54	0.73
Linear	1	9.26*	4.88	0.96	103.14**	12.86**	2.41	1.33
Quadratic	1	0.82	0.15	0.10	3.41	0.10	0.12	0.85
Error mean square		2.563×10^{-3}	1.735×10^{-4}	4.800×10^{-2}	6.357×10^{-3}	1.350×10^{-4}	2.433	7.828×10^{4}
Error degrees of freedom		9	9	9	9	9	9	9

*, ** = significant at the 5% and 1% levels of probability, respectively.

Appendix Table 12. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 10 August and 16 October, 1982.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		--------	--------	--------	F values	--------	--------	--------
Harvest 1 (10 August)								
Block	3	0.08	0.47	0.63	2.32	1.06	0.40	1.62
Salinity	3	0.38	64.06**	3.28	3.23	1.15	4.79*	13.00**
Linear	1	0.42	159.59**	6.94*	8.15*	0.00	0.06	30.20**
Quadratic	1	0.09	29.70**	2.91	1.43	0.17	8.66*	2.39
Error mean square		4.307×10^{-3}	2.544×10^{-5}	2.949×10^{-2}	2.105×10^{-2}	3.022×10^{-4}	1.467	1.395×10^{5}
Error degrees of freedom		9	9	9	9	9	9	9
Harvest 2 (16 October)								
Block	3	0.18	0.35	0.34	1.97	0.21	5.43*	3.90*
Salinity	3	1.48	13.69**	0.91	6.50*	4.42*	2.77	22.30**
Linear	1	3.56	27.37**	0.75	15.48**	0.34	6.32*	54.20**
Quadratic	1	0.02	7.62*	0.29	3.72	0.88	1.00	5.69*
Error mean square		2.824×10^{-3}	1.156×10^{-4}	4.419×10^{-2}	5.365×10^{-2}	6.888×10^{-5}	6.829×10^{-1}	3.287×10^{3}
Error degrees of freedom		9	9	9	9	9	9	9

*, ** = significant at the 5% and 1% levels of probability, respectively.

Appendix Table 13. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with four levels of salinity, Brazito sandy loam soil, 30 June and 24 August, 1983.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		----------	----------	----------	F values	----------	----------	----------
Harvest 1 (30 June)								
Block	3	7.68**	2.16	0.82	0.38	3.63	1.49	23.80**
Salinity	3	7.46**	43.64**	0.65	12.48**	5.38*	0.69	11.46**
Linear	1	11.63**	103.70**	0.04	24.20**	4.40	0.30	19.28**
Quadratic	1	0.06	23.86**	0.22	12.49**	2.26	0.82	3.33
Error mean square		$7.908x10^{-4}$	$6.819x10^{-5}$	$4.383x10^{-2}$	$5.971x10^{-2}$	$1.612x10^{-4}$	3.655	$1.415x10^{5}$
Error degrees of freedom		9	9	9	9	9	9	9
Harvest 2 (24 August)								
Block	3	1.09	4.04	2.32	1.05	3.01	1.25	1.33
Salinity	3	0.90	25.65**	4.84*	1.43	2.70	0.07	2.34
Linear	1	0.69	74.18**	12.02*	4.16	2.14	0.19	0.00
Quadratic	1	1.80	9.64*	5.68*	0.78	3.67	0.00	6.24*
Error mean square		$1.263x10^{-3}$	$1.006x10^{-4}$	$1.348x10^{-2}$	$1.716x10^{-2}$	$1.857x10^{-4}$	3.675	$5.741x10^{5}$
Error degrees of freedom		7	7	7	7	7	7	9

*, ** = significant at the 5% and 1% levels of probability, respectively.

Appendix Table 14. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with four levels of salinity, Brazito sandy loam soil, 23 August, 1982.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Block	3	0.10	0.98	0.21	0.72	1.38	0.59	0.78
Salinity	3	0.70	77.11**	6.67*	0.64	0.43	0.61	4.31*
Linear	1	1.59	191.54**	11.34**	1.69	0.05	0.57	8.37*
Quadratic	1	0.48	36.78**	7.52*	0.03	0.50	0.87	0.89
Error mean square		$3.703x10^{-3}$	$2.169x10^{-5}$	$2.442x10^{-2}$	$7.182x10^{-2}$	$7.266x10^{-4}$	1.339	$2.562x10^{5}$
Error degrees of freedom		8	8	8	8	8	9	9

*, ** = significant at the 5% and 1% levels of probability, respectively.

Appendix Table 15. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with four levels of salinity, Brazito sandy loam soil, 13 July and 7 September, 1983.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Harvest 1 (13 July)								
Block	3	0.55	1.08	2.23	0.85	5.21*	0.66	3.59
Salinity	3	3.51	3.83	2.76	11.78**	7.12**	1.08	5.10*
Linear	1	6.62*	9.15*	0.75	28.01**	0.30	1.62	1.61
Quadratic	1	0.68	1.96	1.03	10.61*	10.35*	0.78	5.56*
Error mean square		2.066×10^{-3}	2.738×10^{-4}	1.008×10^{-2}	4.888×10^{-2}	6.406×10^{-5}	3.068	3.568×10^{-5}
Error degrees of freedom		9	9	9	9	9	9	9
Harvest 2 (7 September)								
Block	3	3.04	0.35	1.02	1.27	0.46	1.33	0.45
Salinity	3	1.75	1.55	1.54	16.84**	0.77	0.49	1.31
Linear	1	2.13	3.60	0.20	29.79**	0.97	0.17	1.12
Quadratic	1	0.37	0.53	2.81	9.18*	0.14	0.62	0.66
Error mean square		7.672×10^{-4}	9.116×10^{-4}	6.686×10^{-2}	2.016×10^{-2}	6.513×10^{-4}	2.475	1.211×10^{6}
Error degrees of freedom		4	4	4	4	4	4	9

*, ** = significant at the 5% and 1% levels of probability, respectively.

Appendix Table 16. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with three levels of salinity, Glendale clay loam soil, 14 May, 23 June and 11 August, 1982.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Harvest 1 (14 May)								
Block	3	6.51*	0.22	2.98	0.21	2.13	3.70	1.36
Salinity	2	2.58	0.65	2.65	0.93	2.48	0.14	0.47
Linear	1	4.88	0.00	0.86	1.33	0.32	0.00	0.21
Error mean square		9.188×10^{-4}	7.546×10^{-4}	1.586×10^{-2}	1.650×10^{-2}	1.055×10^{-4}	1.327	4.448×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 2 (23 June)								
Block	3	1.30	1.18	1.21	2.49	1.03	2.27	1.01
Salinity	2	4.40	0.87	0.73	0.55	0.92	0.27	1.95
Linear	1	4.36	1.06	1.46	0.17	0.46	0.54	0.82
Error mean square		1.648×10^{-3}	1.881×10^{-4}	2.505×10^{-2}	2.852×10^{-2}	9.887×10^{-5}	5.253×10^{-1}	3.546×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 3 (11 August)								
Block	3	0.72	0.84	0.64	1.77	0.65	3.66	3.94
Salinity	2	3.02	1.03	0.44	0.14	1.04	0.10	3.33
Linear	1	2.46	1.11	0.53	0.20	0.79	0.16	2.79
Error mean square		3.916×10^{-3}	2.503×10^{-4}	4.680×10^{-2}	1.908×10^{-2}	1.242×10^{-4}	6.837×10^{-1}	2.613×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6

* = significant at the 5% level of probability.

Appendix Table 17. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the anthesis stage with three levels of salinity, Glendale clay loam soil, 27 June and 26 August, 1983.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		-----	-----	-----	F values	-----	-----	-----
Harvest 1 (27 June)								
Block	3	4.22	1.19	0.78	1.11	5.77*	2.65	5.68*
Salinity	2	6.20*	0.22	0.14	2.24	0.60	1.96	1.06
Linear	1	2.45	0.40	0.23	3.99	0.29	1.01	0.97
Error mean square		2.822×10^{-3}	1.602×10^{-4}	7.902×10^{-4}	1.756×10^{-1}	2.210×10^{-4}	6.272	3.294×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 2 (26 August)								
Block	3	4.43	169.33	453.94*	3.01	7.95	6.73	0.61
Salinity	2	2.25	42.59	255.69*	2.57	9.11	3.88	0.44
Linear	1	4.50	32.92	56.67	3.80	0.46	1.11	0.45
Error mean square		9.048×10^{-4}	3.060×10^{-6}	1.056×10^{-3}	1.967×10^{-3}	4.096×10^{-5}	6.320×10^{-1}	9.335×10^{6}
Error degrees of freedom		1	1	1	1	1	1	6

* = significant at the 5% level of probability.

Appendix Table 18. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with three levels of salinity, Glendale clay loam soil, 21 May, 16 July and 15 September, 1982.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield
		F values						
Harvest 1 (21 May)								
Block	3	0.58	1.47	4.13	0.27	0.81	0.25	2.11
Salinity	2	5.08	0.91	2.76	4.72	0.79	0.32	0.77
Linear	1	9.97*	0.76	3.10	9.23*	1.24	0.05	0.01
Error mean square		3.534×10^{-3}	1.515×10^{-4}	1.522×10^{-2}	3.727×10^{-2}	1.724×10^{-4}	1.490	5.654×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 2 (16 July)								
Block	3	2.59	0.46	0.23	0.78	0.85	2.01	3.29
Salinity	2	1.33	0.03	0.72	0.22	1.61	0.18	4.07
Linear	1	0.48	0.04	1.44	0.23	0.83	0.37	0.36
Error mean square		3.499×10^{-3}	7.775×10^{-4}	6.928×10^{-2}	2.276×10^{-2}	9.017×10^{-5}	9.133×10^{-1}	5.350×10^{5}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 3 (15 September)								
Block	3	3.45	1.24	4.19	0.16	0.40	5.21	5.47*
Salinity	2	0.12	1.04	1.63	0.16	0.21	3.44	1.36
Linear	1	0.01	0.58	1.61	0.09	0.07	3.24	1.93
Error mean square		2.431×10^{-3}	1.581×10^{-4}	2.222×10^{-2}	4.381×10^{-2}	3.062×10^{-4}	4.792×10^{-1}	8.151×10^{4}
Error degrees of freedom		5	5	5	5	5	5	5

* = significant at the 5% level of probability.

Appendix Table 19. Analyses of variance for mineral percentages, crude protein percentage, and dry forage yield of saltgrass at the post-anthesis stage with three levels of salinity, Glendale clay loam soil, 13 July and 12 September, 1983.

Source	Degrees of freedom	Ca	Mg	K	Na	P	Crude protein	Dry forage yield†
		F values						
Harvest 1 (13 July)								
Block	3	0.80	3.28	1.48	1.11	5.71*	0.27	0.93
Salinity	2	0.23	19.13**	1.37	2.24	16.26**	2.72	0.61
Linear	1	0.14	4.75	1.55	3.99	2.96	1.74	1.07
Error mean square		6.416×10^{-3}	3.591×10^{-5}	3.379×10^{-2}	1.756×10^{-1}	7.548×10^{-5}	3.525	3.147×10^{6}
Error degrees of freedom		6	6	6	6	6	6	6
Harvest 2 (12 September)								
Block	2	0.47	3.35	8.84	23.23	0.72	1.41	2.59
Salinity	2	0.09	7.43	3.43	46.63	0.05	1.34	0.02
Linear	1	0.16	14.44	6.80	93.24	0.03	1.08	0.03
Error mean square		1.529×10^{-2}	8.281×10^{-5}	6.906×10^{-3}	3.546×10^{-3}	1.525×10^{-4}	3.612×10^{-1}	1.930×10^{6}
Error degrees of freedom		1	1	1	1	1	1	6

†Three degrees of freedom for dry forage yield.
*, ** = significant at the 5% and 1% levels of probability, respectively.

A D D E N D U M

EFFECT OF VARIOUS HERBICIDES ON SALTGRASS

Introduction

A native species that has potential as a forage crop and exhibits a high degree of salt tolerance is saltgrass (Distichlis spicata (L.) Greene). However, there has been little agronomic research done to date on saltgrass. Weed control is fundamental to establishment and maintenance of a productive stand of saltgrass. Accordingly, this study investigates the effect of herbicides commonly used to control broadleaf and grass weeds on saltgrass growth.

Materials and methods

This study was conducted in the greenhouse at the Fabian Garcia Horticultural Farm. Plastic pots, 20 cm in diameter, were filled with 5,000 g of Brazito very fine sandy loam. Saltgrass rhizomes were collected from the vicinity of the Mesilla Dam, and 50 g of rhizome material was planted in each pot on 9 February. The pots were watered with normal tap water every 3 or 4 days to maintain the soil at or near field capacity. Pots were fertilized with 15-30-15 ($N-P_2O_5-K_2O$) fertilizer on 11 March, 11 April, and 11 May for a total of 0.44 g N/pot, 0.38 g P/pot, and 0.37 g K/pot. Greenhouse temperatures ranged from 29C at night to 35C during the day.

Herbicides were applied to the saltgrass on 9 May. There were three replications of each treatment, arranged in a randomized block design. The herbicides used, and the rates applied, are shown in Table 21. All herbicides were applied as a spray with the exception of dicamba (Banvel 5G) which was applied as a pellet. Each of the rates used were rates recommended by the manufacturer. On 23 May, the pots were harvested 2.5 cm above the soil surface, and the saltgrass was dried and weighed for determination of dry forage weights. Immediately before harvesting, a visual

Table 21. Effect of herbicide treatments on dry weights and color of saltgrass.

Herbicide (trade name)	Herbicide (common name)	Rate (herbicide)	Rate (active ingredient)	First harvest Dry weight	First harvest Color rating	Second harvest Dry weight	Third harvest Dry weight
		---kg/ha---	-------kg/ha-------	-g/pot-		-g/pot-	-g/pot-
Karmex 80W	Diuron	2.8	2.2	12.70	3.8	2.20	4.00
		4.5	3.6	12.03	3.8	1.27	2.67
Sinbar 80W	Terbacil	2.2	1.8	14.13	2.7	1.03	3.32
		4.5	3.6	14.33	2.3	0.20	1.49
		9.0	7.2	11.87	2.8	0.23	0.00
Dacthal W-75	DCPA	9.0	6.7	12.67	4.0	5.03	3.80
Banvel 5G	Dicamba	112.1	5.6	10.37	2.2	0.06	0.00
Sencor 50WP	Metribuzin	1.1	0.6	11.07	4.0	3.50	4.69
Untreated	---	--	--	12.76	3.7	5.11	4.45
Mean				12.44	3.3	2.07	2.71
$LSD_{0.05}$				ns	1.0	1.18	1.61
C.V.%				22.57	18.8	33.97	35.13

Scale: 1-5; 1 = completely yellow; 5 = greenest.

color rating was given to each pot to note any chlorosis. The color scale was from 1 to 5, with 1 representing completely yellow, and 5 representing the greenest. The saltgrass was then allowed to regrow and was harvested again on 22 June to determine the effect of the herbicide treatments on regrowth. A third harvest was taken on 22 July to determine if the saltgrass could recover from the herbicide treatments.

Results

The dry weights of the saltgrass at the first, second, and third harvests and the color rating at the first harvest are shown in Table 21 for each herbicide treatment. At the first harvest, no significant differences in dry weights were observed as the herbicides did not reduce dry weights relative to the untreated control. However, there was obvious chlorosis of the saltgrass with the use of dicamba (Banvel 5G) and terbacil (Sinbar 80W). At the second harvest, all herbicides except DCPA (Dacthal W-75) caused significantly lower dry weights than the untreated control. Dry weights of saltgrass treated with metribuzin (Sencor 50WP) were significantly lower than the control, but were not as low as the yields from pots treated with dicamba (Banvel 5G), terbacil (Sinbar 80W) or diuron (Karmex 80W). At the third harvest, saltgrass treated with dicamba (Banvel 5B) and 9 kg/ha of terbacil (Sinbar 80W) were completely dead and no yields were recorded. However, saltgrass treated with diuron (Karmex 80W) at 2.8 kg/ha, terbacil (Sinbar 80W) at 2.2 kg/ha and metribuzin (Sencor 50WP) had recovered and yields were not significantly different from the untreated control. The dry weights of the saltgrass treated with diuron (Karmex 80W) and terbacil (Sinbar 80W) were proportional to the rates applied.

Conclusions

The herbicide DCPA (Dacthal W-75) did not affect the dry weights, and could be used in saltgrass. Metribuzin (Sencor 50WP) slightly reduced dry weights at the second harvest, but could also be used in saltgrass. Low rates of diuron (Karmex 80W) and terbacil (Sinbar 80W) reduced dry weights but the saltgrass was able to recover from the herbicide treatments by the third harvest. Higher rates significantly damaged the saltgrass and these rates would be too high for use. The highest rate of terbacil (Sinbar 80W) and dicamba (Banvel 5G) completely killed the saltgrass.