Survival of Plant Species as a Function of Salinity and Slope Position

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ABSTRACT

An experiment was conducted during 1995-1997 at Truscott Brine Lake, Truscott, TX to determine whether any of 38 salt tolerant plant species could survive salt conditions at Truscott Brine Lake and tolerate the summer heat and winter cold of northwest Texas. Little is known regarding survival and growth of species native to salt marsh conditions of southern United States coastal regions with respect to climate which is more xeric and having a wider range of temperature extremes than coastal areas. The objective of this study was to examine the effect of pond salinity and shoreline position (proximity to pond edge) on survival of salt tolerant species and to determine which species may have potential to survive in this environment. Species selection was based on salt tolerance in Gulf and Atlantic coastal areas and in arid western U.S. Species were planted in and around 1-acre circular research ponds, 3 filled with high saline water (termed 'salt water') and 3 filled with less saline water (termed 'fresh water'). Species were planted in spoke arrangements beginning near the center of each pond and radiating outward. Each pond contained a spoke for each species, spokes were spaced uniformly, and species were assigned randomly to spokes within a pond. Three slope positions were designated on each pond spoke to correspond to 3 levels of plant submergence. These levels were position 1: never submerged; position 2: periodically submerged; and position 3: continuously submerged. Water was pumped periodically into each pond to maintain predetermined water levels. Species survival was affected by species genetics, slope position, pond x slope, species x slope, and pond x species x slope interaction. Species survival decreased as the level of submergence increased. In the summer of 1995 there was little effect of slope on species survival, but by the fall of 1997 slope positions 1, 2, and 3 had only 48%, 29%, and 9% survival, respectively. Survival rate decreased by 20% with each slope increment. Based on percentage survival sand cordgrass, saltmeadow cordgrass selection 9067788, and common reed are viable species for use on all slopes in fresh water. Saltmeadow cordgrass var. 'Sharp', 'selection 9067788', and 'Flageo' along with common reed and sand cordgrass are viable species in salt water.

KEYWORDS: Salinity, Slope, Ponds, Plant Species, Survival, Saltmeadow cordgrass

Two primary factors controlling plant establishment in saline soils are seedbed environment and the selected plant materials. Therefore, plant establishment on saline soils is dependent on water and temperature dynamics and plant adaptations which provide avoidance or tolerance to environmental stress. Soluble salts impact growth by limiting water availability (Bernstein 1961). As salt concentrations increase there is a corresponding decrease in osmotic potential of the soil solution, hence, a decline in available water. In arid and semi-arid environments, salinity interacts with temperature and precipitation to limit seed germination and seedling growth (US Salinity Laboratory Staff 1954, Caldwell 1974). A plant's capacity to tolerate, exclude or store specific ions and adjust osmotically to maintain a favorable internal water balance may be a key factor influencing salt tolerance. Some halophytes may dilute accumulated ions by increasing succulence (Caldwell 1974). The U.S. Army Corps of Engineers designed a project to collect and divert water from naturally saline streams in north Texas in an effort to reduce the salt load in downstream rivers and lakes. Truscott Brine Lake was a part of this project, entitled "U.S. Army Corps of Engineers' Red River Chloride Control Project." Truscott Brine Lake was created by capturing salt water flowing from natural springs using an inflatable low water dam, pumping the salt water several miles, and impounding it to form a salt lake near Truscott. During times of low rainfall the dam was inflated and captured water was pumped to Truscott. During periods of significant rainfall runoff, the dam was deflated and water was allowed to move downstream in a normal manner. The salt content of the spring water was thus diluted. As a result of above normal rainfall on the salt lake's watershed, the water level rose faster than anticipated. Useful life of the lake was determined by how much water could be evaporated or transpired from the lake relative to the amount of water which flowed into the lake. The faster than anticipated rise of the water in the lake threatened to shorten the useful life. It was hypothesized that plants growing near the perimeter of the salt lake or in shallow water might increase the amount of water loss from the lake by transpiring water in excess of normal evaporation from the water surface and therefore increase its life (Cox et al. 1996). Higher evapotranspiration from the lake would create a sink for additional water. In addition, any vegetation which could be induced to grow around the salty perimeter of the lake might provide food and habitat for wildlife. The objective discussed in this paper was to screen salt tolerant species that could survive and thrive in water that collected in Truscott Brine Lake.

MATERIALS AND METHODS

The study was conducted on a 7.4 acre area at the U. S. Army Corps of Engineers' Truscott Saline Collection Area ($33^0$52'N, $99^0$52'W, elevation 2450 ft), about 2 miles northwest of the town of Truscott in northwest Texas. The soil parent material consists of sandstone and limestone. The soil type was Vernon clay which is classified as fine, mixed thermic Typic Ustochrept. The long term average annual precipitation of this area is 24.88 inches, occurring mostly between the months of April and October (see Fig. 1 for distribution).

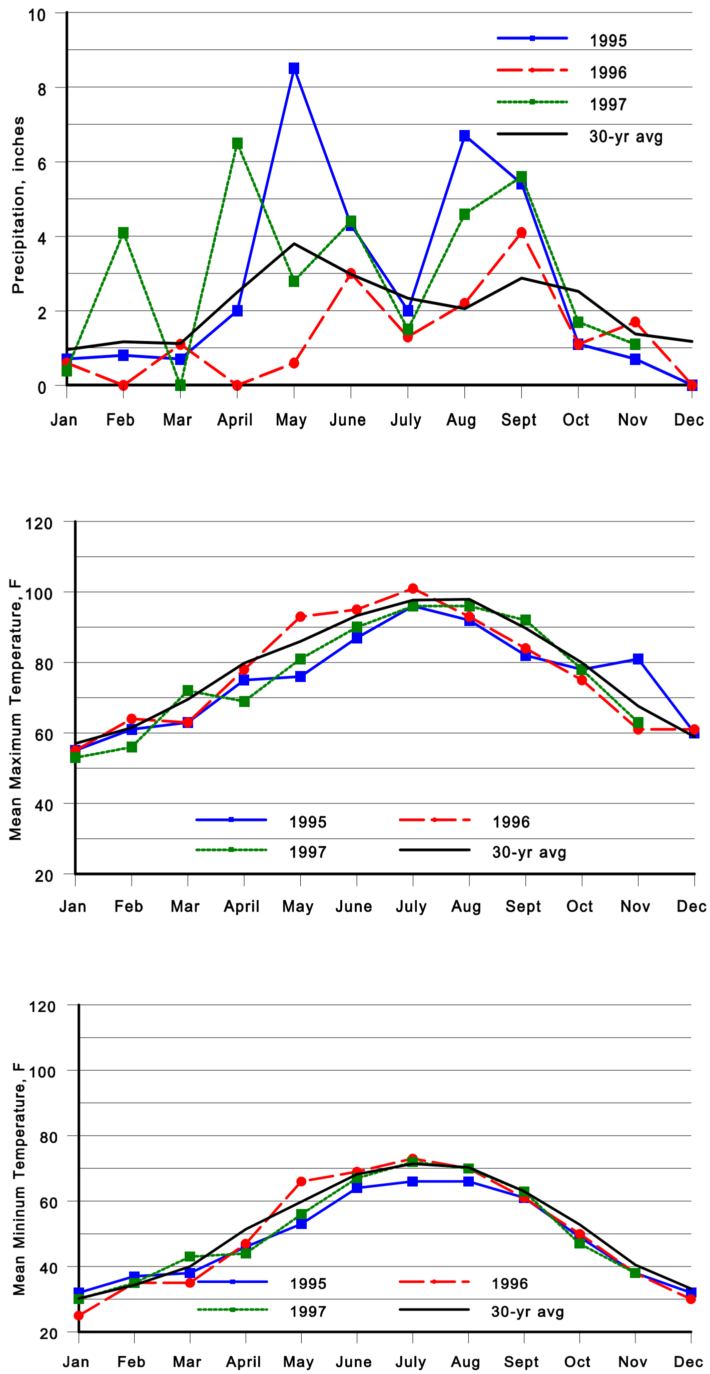

Figure 1. Monthly precipitation, mean maximum and minimum temperatures at Truscott in 1995, 1996, and 1997 and 30 year monthly means from Munday, TX (nearest station).

Pond Construction and Pump Stations

During the spring of 1995, six circular ponds were constructed adjacent to Truscott Brine Lake. Each pond was approximately 100 ft in diameter and 6.5 ft deep in the center. Each was outfitted with a removable stand pipe near the pond center and connected to an underground drain pipe. This allowed ponds to be emptied into a nearby drainage ditch when the stand pipe was removed. The Corps of Engineers constructed an earthen dam to create a fresh water source. Water captured by this dam flowed through natural drainage to an area near the test ponds. A channel from the main body of the salt lake, approximately 600 ft long, was constructed to provide a salt water source near each pond. Two pump stations were established to supply either highly saline water (termed "saltwater") or slightly saline water (termed "fresh water"). Portable pump stations powered by gasoline engines provided water for each pond. Pumps had a 3 inch discharge and were capable of filling an empty pond in less than 4 hours. Water was pumped from each source as needed and was conveyed to each pond using several sections of 4 inch diameter flexible rubber hose equipped with quick connectors. The discharge end of the rubber hoses was attached to a 30 ft long joint of 4 inch PVC pipe. Water was discharged near the center of each pond. The PVC pipe stabilized the discharge line and reduced the amount of erosion and sedimentation in each pond. Prior to planting, ponds were filled twice with fresh water to seal leaks by swelling the clay soil.

Species Selection

Species selection was based on a thorough review of literature to identify species which were tolerant of salt and could be adapted in this hot and dry environment. Species selection was also based on: (1) advice from U.S.D.A. plant material centers' experts located along the Gulf and Atlantic coasts and in arid western states and (2) from commercial businesses involved in shoreline restoration projects. A complete list of species is given in Table 1.

Table 1. Plant species raised in fresh water and salt water ponds.

Common name	No.	Scientific name	Variety
Alkali sacaton	41	*Sporobolus airoides*	Salado
American beachgrass	18	*Ammophila breviligulata*	Cape
Bayberry	9	*Myrica pensylvanica*	Wildwood
Beach plum	8	*Prunus maritina*	Ocean view
Bitter panicum[1]	10	*Panicum amarum*	North PA (from Norwood)
Bitter panicum	39		North PA (from
Coastal panicgrass[2]	24	*Panicum amarum* var.	Atlantic (from Norwood)
Coastal panicgrass	33		Atlantic(from Cape May)
Common reed	37	*Phragmites australis*	ShoreLine
Douglas CWG 94	27		
Glass wort	5	*Salicornia virginica*	
Golden creeper	6	*Ernodea litoralis*	
Gulf cordgrass	21	*Spartin spartinae*	
Hybrid willow	16		Austree
Hycrest #2 CWG 94	26		
Needle/ black rush	2	*Juncus roemerianus*	

Table 1. (Cont'd.)

Common name	No.	Scientific name	Variety
NewHy Miles City 94	25		
Panicum "X"[3]	11		
Prairie cordgrass	38	*Spartina pectinata*	
RS-Hoff natural hybrid E93	29		
RWR Syn A 94	28		
Salt meadow cordgrass	36	*Spartina patens*	Sharp
Saltbush	15	*Atriplex lentiformis*	Playa
Saltmeadow cordgrass	22	*Spartina patens*	Selection 9067788
Saltmeadow cordgrass	34		Avalon
Saltmeadow cordgrass	35		Flageo
Saltwort	7	*Batis maritina*	
Sand cordgrass	30	*Spartina bakerii*	
Sea oats	13	*Uniola paniculata*	
Sea myrtle	12	*Baccharis halimifolia*	
Seas ox-eye daisy	4	*Borrichia frutescens*	
Seashore paspalum	23	*Paspalum vaginatum*	
Seashore saltgrass	31	*Distichlis spicata*	
Seashore dropseed	40	*Sporobolus virginicus*	
Smooth cordgrass	1	*Spartina alterniflora*	Vermilion
Smooth cordgrass	19		Bayshore
Soft rush	42	*Juncus effusus*	
Soft stem bullrush	32	*Scirpus validus*	
Sweet grass	20	*Muhlenbergia filipses*	
Torpedo grass	17	*Panicum repens*	

[1]Species 10 is identical to species 39 but from different sources.
[2]Species 24 is identical to species 33 but from different sources.
[3]A selection made by Mr. Ben Norwood, Norwood Farms, McBee, S.C. from a seed production field. Ancestry and availability are uncertain.

Production of Plants

Plants for several of the species were produced from seeds. These were seeded in small cones approximately 1.6 inches in diameter and 10 inches long. Other species were ordered from commercial nurseries or USDA-NRCS Plant Materials Centers as seedlings or rooted cuttings. Seed, seedlings, and rooted cuttings were grown in a 1:3 mixture of peat moss and field soil. All species were grown in a greenhouse at the Texas Agricultural Experiment Station at Munday in Knox County, TX.

Determination of Slope Divisions

After planting, each spoke was divided into 3 sections, each containing 6 plants of one of the species. Since species had different growth habits water level in each section could not be determined before planting. Water depths which submerged 6 and 12 plants in each slope were determined for each pond. Since the ponds were not identical, these depths varied among ponds. This was done by taking elevation shots with a dumpy level between plants 6 and 7 and between plants 12 and 13 at several locations within each pond. The average of the readings taken between plants 6 and 7 in a given pond became the high water level and the average of the readings taken between plants 12 and 13 became the low water level for the respective ponds. These two elevations were marked on the drain pipe of each pond allowing an easy and quick method to determine whether the pond was low on water and when it was full. Because each pond was not constructed perfectly symmetrical, the number of plants above each water level varied slightly between spokes within a pond. Likewise, the depth of water between the two water marks varied among ponds because of the different side slopes.

Transplanting Species

Each pond was divided into 40 equal sections radiating from the center. One species was planted within each section in a single row. Rows formed a spoke pattern within a pond. Each row consisted of approximately 20 plants spaced 2 ft apart. Because of growing problems in the greenhouse, three species had less than the needed number of plants; therefore, spacing on these was increased in order to have an equal number of plants within each water depth. The exceptions to plant spacing were smooth cordgrass 'Vermilion' (4 ft spacing), beach plum 'Ocean View' (4 ft spacing), and bayberry 'Wildwood' (6 ft spacing). Species were randomly assigned a spoke position within each pond. The three slope sections were designated as the upper slope where plants were never submerged; mid-slope, where plants were periodically submerged; and lower slope where plants were submerged at all times. The 5 ft of each spoke nearest the pond center was not planted. The initial planting was done on May 23 and 24, 1995 with additional species planted on June 27 and 28, 1995. Two species, coastal panicgrass 'Atlantic' and bitter panicum 'North PA', were duplicated in the planting of each pond; however, plants were obtained from two different sources. Species 3 and 14 were also duplicates from different sources, but were dropped from the study because of insufficient numbers of plants.

Pond Treatment Watering Schedule

Immediately after the May transplanting, ponds were filled with fresh water to provide each species an opportunity to establish. Ponds were filled a second time prior to the June planting. Ponds were drained a few hours after each filling. Ponds were allowed to dry sufficiently to allow foot traffic before making the June planting. Following June planting ponds were again flooded twice with fresh water and drained as before. On August 1, 1995 three ponds were filled with salt water and three were filled with fresh water. Thereafter ponds had water added on a weekly basis during spring, summer and early fall. During the months when freezing was likely, water was added approximately every two weeks. Water was added to ponds as the water level approached the lower mark on a standpipe and filled to near the upper mark. Not all ponds received water at the same time or the same amount of water.

Observations and Data Analyses

The first plant count was taken immediately following each planting in 1995 and the last in October, 1997. Plant counts were recorded twice each year for each spoke. Ponds were drained approximately 10 days prior to counting and refilled after counting. Data regarding plant species survival on each slope section and for each spoke were calculated by the following formula: [(total number of plants surviving in the fall of 1997) x 100] / (Total number of plants initially planted in 1995).

The experimental design was a split-split plot. Ponds were considered main plots and were replicated three times. Species or spokes were considered subplots and slope position within a spoke was considered a sub-subplot. Data were analyzed with SAS computer programming release 6.12 using Proc GLM (SAS Institute 1996). Analyses of variance and probability levels were calculated using appropriate error terms.

RESULTS AND DISCUSSION

The species selected for use in this study were subjected to water with an extremely high salt load, wide fluctuations in annual precipitation, and numerous days with minimum temperatures below freezing. In 1995 and 1997 total annual precipitation (Fig. 1) exceeded average annual precipitation (24.88 inches) by about 8 inches while in 1996 annual precipitation was about two-thirds (16 inches) the annual average. Mean maximum temperatures were highest in 1996 and lowest in 1995. Temperatures fell below freezing (November through March) for 45 and 44 days in 1995-96 and 1996-97, respectively. All of these factors combined to influence the survivability of the species used. No attempt was made to determine which factor or combination of factors made species more susceptible. Overall percentage of plants per spoke that survived for 2.5 years was not affected by water salinity ($P = 0.6799$); about 30% of all plants survived in the fresh water versus 27% in the salt water. However, survival rate among species differed significantly ($P < 0.001$). Survival of species was also affected by species x water type interaction ($P < 0.001$), slope position ($P < 0.001$), slope x species ($P < 0.001$), and salinity x species x slope ($P < 0.001$) interaction. For example, a species may have survived significantly better in fresh water than in salt water on the upper slope.

Saltmeadow cordgrass, selection 9067788, had the highest survival rate (85%), whereas prairie cordgrass had the least survival (< 1%) (Table 2). Species not surviving in both types water included beach plum 'Ocean View', Douglas CWG 94, golden creeper, Hycrest #2 CWG 94, RS-Hoff natural hybrid E93, saltwort, and torpedo grass. Although species survival was significantly affected by slope position, salinity x slope interaction did not affect species survival ($P = 0.1087$). Species survival decreased on the lower portion of the slopes. Upper slope, mid-slope, and lower slope sections had 48, 29, and 9% of the plants surviving when averaged across salinity and species (Table 2). Overall, species survival decreased about 20% per slope increment toward the pond centers. Even though species survival among slope positions differed significantly, saltmeadow cordgrass, selection 9067788, had the highest survival on all slopes. On the upper slope, gulf cordgrass also had 100% survival, but prairie cordgrass had < 3% survival; 9 of 38 species did not survive on this slope. On the mid-slope, 17 species had survival <6%, and on lowest slope, 26 species had survival <3%.

Table 2. Percent of plants surviving 2.5 years after planting at the Truscott Brine Lake by species, salinity, and slope position (1-3), Truscott, TX.

Species	Fresh Water				Salt Water				Average			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Alkali sacaton	88.9	27.8	0.0	38.9	83.3	38.9	0.0	40.7	86.1	33.3	0.0	39.8
American beachgrass, 'Cape'	27.8	0.0	0.0	9.3	0.0	0.0	0.0	0.0	13.9	0.0	0.0	4.6
Bayberry, 'Wildwood'	16.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	8.3	0.0	0.0	2.8
Beach plum, 'Ocean View'	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bitter panicum, 'North PA' (from Brooksville)	100.0	72.2	16.7	63.0	83.3	16.7	0.0	33.3	91.7	44.4	8.3	48.1
Bitter panicum, 'North PA' (from Norwood)	100.0	55.6	22.2	59.3	77.8	11.1	0.0	29.6	88.9	33.3	11.1	44.4
Coastal panicgrass, 'Atlantic' (from Cape May)	100.0	77.8	0.0	59.3	88.9	33.3	0.0	40.7	94.4	55.6	0.0	50.0

Table 2. (Cont'd)

Species	Fresh Water				Salt Water				Average			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Coastal panicgrass, 'Atlantic' (from Norwood)	100.0	83.3	5.6	63.0	83.3	16.7	0.0	33.3	91.7	50.0	2.8	48.2
Common reed	94.4	77.8	61.1	77.8	94.4	83.3	44.4	74.1	94.4	80.6	52.8	75.9
Douglas CWG 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glass wort	0.0	0.0	0.0	0.0	0.0	22.2	0.0	7.4	0.0	11.1	0.0	3.7
Golden creeper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gulf cordgrass	100.0	77.8	16.7	64.8	100.0	88.9	0.0	63.0	100.0	83.3	8.3	63.9
Hybrid willow	38.9	0.0	0.0	13.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0	6.5
Hycrest #2 CWG 94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Needle/ black rush	61.1	100.0	22.2	61.1	88.9	72.2	22.2	61.1	75.0	86.1	22.2	61.1
NewHy Miles City 94	16.7	11.1	0.0	9.3	0.0	0.0	0.0	0.0	8.3	5.6	0.0	4.6
Panicum "X"1	94.4	55.6	5.6	51.9	88.9	16.7	0.0	35.2	91.7	36.1	2.8	43.5
Prairie cordgrass	0.0	0.0	0.0	0.0	5.6	0.0	0.0	1.9	2.8	0.0	0.0	0.9
RS-Hoff natural hybrid E93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RWR Syn A 94	27.8	0.0	0.0	9.3	22.2	0.0	0.0	7.4	25.0	0.0	0.0	8.3
Salt bush	88.9	11.1	0.0	33.3	100.0	22.2	0.0	40.7	94.4	16.7	0.0	37.0
Saltmeadow cordgrass, selection 9067788	100.0	100.0	50.0	83.3	100.0	100.0	61.1	87.0	100.0	100.0	55.6	85.2
Saltmeadow cordgrass, 'Flageo'	94.4	61.1	22.2	59.3	100.0	100.0	22.2	74.1	97.2	80.6	22.2	66.7
Saltmeadow cordgrass, 'Sharp'	83.3	33.3	22.2	46.3	100.0	100.0	83.3	94.4	91.7	66.7	52.8	70.4
Saltmeadow cordgrass, 'Avalon'	94.4	55.6	33.3	61.1	100.0	100.0	38.9	79.6	97.2	77.8	36.1	70.4
Saltwort	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand cordgrass	94.4	100.0	50.0	81.5	91.7	72.2	11.1	58.3	93.1	86.1	30.6	69.9
Sea ox-eye daisy	83.3	33.3	0.0	38.9	94.4	16.7	0.0	37.0	88.9	25.0	0.0	38.0
Sea oats	16.7	0.0	0.0	5.6	0.0	0.0	0.0	0.0	8.3	0.0	0.0	2.8
Sea myrtle	83.3	11.1	0.0	31.5	61.1	0.0	0.0	20.4	72.2	5.6	0.0	25.9
Seashore saltgrass	83.3	41.7	0.0	41.7	100.0	94.4	55.6	83.3	91.7	68.1	27.8	62.5
Seashore paspalum	5.6	0.0	0.0	1.9	50.0	11.1	0.0	20.4	27.8	5.6	0.0	11.1
Seashore dropseed	61.1	5.6	0.0	22.2	83.3	5.6	0.0	29.6	72.2	5.6	0.0	25.9
Smooth cordgrass, 'Vermilion'	0.0	0.0	0.0	0.0	0.0	33.3	11.1	14.8	0.0	16.7	5.6	7.4
Smooth cordgrass, 'Bayshore'	27.8	0.0	0.0	9.3	17.8	44.4	16.7	26.3	22.8	22.2	8.3	17.8
Soft stem bullrush	38.9	88.9	16.7	48.1	0.0	5.6	5.6	3.7	19.4	47.2	11.1	25.9
Soft rush	27.8	33.3	0.0	20.4	0.0	0.0	0.0	0.0	13.9	16.7	0.0	10.2
Sweet grass	94.4	27.8	0.0	40.7	0.0	0.0	0.0	0.0	47.2	13.9	0.0	20.4
Torpedo grass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	51.1	31.0	8.6	30.3	45.4	27.6	9.3	27.4	48.2	29.3	9.0	28.8

As reported earlier, species survival was affected by salinity x species x slope interaction. On upper slope of both water types, gulf cordgrass and saltmeadow cordgrass, selection 9067788, survived 100%. Bitter panicum (both sources) and coastal panic grass (both sources) had 100% survival in fresh water whereas saltmeadow cordgrass (var. 'Flageo', 'Sharp', and 'Avalon'), salt bush, and seashore saltgrass had 100% survival in salt water. On the mid-slope section, saltmeadow cordgrass, selection 9067788, survived 100% in both water types, sand cordgrass and needle/black rush survived 100% in fresh water, and saltmeadow cordgrass (var. 'Flageo', 'Sharp', and 'Avalon') survived 100% in salt water. No species in either water type had 100% survival on the lower slope. On the lower slope of the fresh water ponds, common reed, saltmeadow cordgrass, selection 9067788, and sand cordgrass had the highest survival (50% or more). On the same slope of the salt water ponds, saltmeadow cordgrass (var. 'Sharp' and 'selection 9067788') and seashore saltgrass had the highest survival (83,61, and 56%, respectively).

CONCLUSIONS

Several of the species chosen for this study flourish naturally in tidal areas along the coast where they are periodically inundated with salt water. In contrast, our study placed them in a situation where they were continually flooded on the lowest slope section and often flooded in the mid-slope section for a significant length of time. Because of this, it was expected that many, if not all, species would not perform well in the lowest slope section and perhaps would not survive in the mid-slope section. Further, it is doubtful that any species capable of growing while fully inundated would be capable of transpiring more water than would be evaporated from a free water surface. Therefore, we concluded that species growing completely inundated probably would not be useful in meeting the eventual project goal of increasing the water lost from the lake.

Transpiration for several of the species was measured to obtain an estimate of water loss. Those results are not the focus of this publication and are not discussed. Vegetation growing at the water's edge would not impede evaporation from the free water surface of the lake and yet would be close enough to the lake to draw water from the lake, thus increasing loss of water from the lake. The benefit to having vegetation growing in the most shallow water would be that as the shoreline receded during times of low runoff and high evaporation and more lake bed became exposed, plants would already be established and would continue to grow and use water. In the event that the lake level increased, plants selected should have the ability to continue to spread up the slope as the water level increased. This could be accomplished through scattering of seeds, rhizomes, or stems which easily root when placed in contact with moist soil. Some of the species requiring less salty water to survive could be established in watershed areas which contribute fresh water to the main lake. Small ponds holding fresh water in the upper reaches of the watershed would also be likely locations for establishment. This will decrease the amount of fresh water entries in the salt lake.

Several species were identified in this study which are capable of surviving around the perimeter of Truscott Brine Lake. These should be successful if grown on areas with relatively flat slopes adjacent to shore lines. These areas with flat slopes will yield larger areas of exposed soil with relatively small drops in water elevation. Several of the species are also capable of sufficient growth to be useful as wildlife habitat.

Additional observations were made with respect to species grown in this study. All varieties/selections of saltmeadow cordgrass, bitter panicum var. North PA, sand cordgrass, panicum "X", gulf cordgrass, and alkali sacaton grew vigorously around the perimeter of salt water. However, these species did not exhibit a great amount of spreading during this study. Other species, such as sea ox-eye daisy and common reed, spread vigorously during the first summer of this study. Sea shore paspalum also spread vigorously the first summer, but was very slow to start regrowth the following spring and never was as vigorous as it had been the first growing season, apparently severely damaged by the winter cold. On the other hand, seashore saltgrass grew rather slowly the first summer but became very vigorous during the second growing season. Sea myrtle grew very well but attracted wildlife that continuously reduced plant numbers. Saltbush spread readily when moisture was present to germinate the abundant seed produced. It was not determined if this seed was useful as a food source for wildlife.

In conclusion, 10 species had 50% or greater survival and tolerated seasonal heat and cold of the Texas Rolling Plains. Common reed, needle/black rush, sand cordgrass, and saltmeadow cordgrass survived on all three slopes in both ponds. Bitter panicum, coastal panic grass, and panicum 'X' survived on the upper slope in both ponds and also on the mid-slope in fresh water ponds. Alkali sacaton, gulf cordgrass, and seashore salt grass survived on both slopes in both ponds; additionally, seashore saltgrass survived on the lower slope in salt water ponds. Saltbush, sea ox-eye daisy, sea myrtle, and seashore dropseed survived on the upper slope in both types of water. Sweet grass survived on the upper slope and soft stem bullrush survived on the mid slope of fresh water ponds. Overall, in salt water ponds saltmeadow cordgrass (all four varieties) had 85% and on the upper two slopes had 100% survival.

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