Revegetation of Oil Well Reserve Pits in West Texas

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Abstract

On-site disposal of drilling fluids frequently causes severe, long-term disturbance of rangeland soils. The effects of mulch on establishment and standing crops of seeded kochia [*Kochia scoparia* (L.) Schrad.], King Ranch bluestem [*Bothriochloa ischaemum* (L.) Keng], Lehmann lovegrass (*Eragrostis lehmanniana* Nees), kleingrass 'Selection 75' (*Panicum coloratum* L.), alkali sacaton [*Sporobolus airoides* (Torr.) Torr.], and fourwing saltbush [*Atriplex canescens* (Pursh) Nutt], and transplanted fourwing saltbush were evaluated on 4, recently covered oil well reserve pits in Reagan County Texas, in 1981 and 1982. On-site disposal of drilling fluids resulted in substantial to large increases in sodium adsorption ratios (SAR) and concentrations of soluble salts, primarily sodium chloride, in reserve pit soils. Mulching with 4,500 kg/ha of weathered hay had no effect, but irrigation was essential for establishment and growth of the seeded species on severely contaminated soils (EC_e 71 to 114 dS m^{-1}, SAR 33 to 127). Mulching improved establishment and yields of seeded King Ranch bluestem and kleingrass on reserve pit soils with EC_e values of 9 to 11 dS m^{-1} and SAR values of 12 to 16. Application of 5.1 cm of supplemental water and mulching reserve pit soils with EC_e values of 3 to 7 and SAR values of 5 to 9 stimulated establishment of competing vegetation, which tended to decrease establishment and yields of seeded and transplanted species. Establishment and yields of transplanted fourwing saltbush were acceptable with or without mulching or irrigation. Survival of fourwing saltbush transplants was near 100% on moderately contaminated soils and 26 to 30% on severely contaminated soils.

Key Words: reclamation, salinity, mulch, rangeland seeding, shrubs

Activities associated with oil and natural gas exploration and production seriously damage large acreages of arid and semiarid rangeland in west Texas. Construction of drilling sites, oil field roads, installation of pipelines, and on-site disposal of drilling fluids reduce forage and browse production, increase susceptibility of soils to erosion, and frequently result in persistent stands of undesirable plants. Oil and gas production activities have caused soil salinity problems on about 174,000 ha of land in Texas (Carl Gray, Texas State Soil and Water Conservation Board, Temple, Texas, unpublished data).

Most oil and gas wells in west Texas are drilled by the rotary method. Typical drilling fluids or muds contain 5% bentonite in fresh water or brine, with sodium hydroxide (NaOH) added as a dispersant, lignite or lignosulfonate to stabilize the slurry, and a density increasing material, usually barite ($BaSO_4$) (Simpson 1975). Quantity and chemical composition of drilling fluids vary with location, depth of drilling, and the individual drilling program.

Reserve pits (earthen basins) about 1 m deep are used for handling, storage, and final disposal of drilling fluids. The fluid, cuttings, and waste materials produced during drilling are usually left in the reserve pit when drilling is completed, allowed to dry and then covered with soil from the pit borders. The soil and drilling residues are often mixed to disperse high concentrations of chemicals. Normal disposal rates of 10 drilling fluid components caused significant growth reductions of beans (*Phaselous vulgaris* L.) and corn [*Zea mays* var. *saccharata* (Sturtev.) Bailey] (Miller et al. 1980). Both organic and inorganic constituents were identified as potential contaminants. High levels of soluble salts or high exchangeable sodium percentages produced by sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$), potassium chloride (KCl), and sodium hydroxide (NaOH) were primary causes of reduced plant growth in 1:1 and 1:4 (v:v) drilling fluid: soil mixtures (Miller and Pesaran 1980). Plant uptake of Zn, Cu, Cd, Pb, and As was directly related to the concentrations of these trace elements added to soils by drilling fluids (Nelson et al. 1984). However, low pH values (<4.0) sufficient to result in significant release to trace elements from drilling fluids are unlikely due to their great neutralizing capacity (Deeley and Canter 1986).

Authority to regulate the disposal of drilling fluid wastes in Texas is held by the Texas Railroad Commission. Accepted disposal methods include landfarming and burial (Statewide Rule 8). On-site disposal of drilling fluids is the common and preferred procedure. However, secondary succession on these sites in arid and semiarid regions is extremely slow due to low precipitation, soil disturbance, and contamination. The relatively high sensitivity of many range grasses to salinity has been reported (Dubetz et al. 1959, Tadmor et al. 1969). Screening potentially useful materials in the field is of critical importance (O'Leary 1984). Controversy over use of native vs. introduced species for disturbed land revegetation has given way to selection of adapted plant materials (Plummer 1977). The effective use of limited supplemental irrigation for establishment of grasses and shrubs on salt-affected soils has been documented (Ries 1980, Dollhopf and Depuit 1981). Straw and other natural mulches usually prevent crusting of the soil surface and reduce soil temperatures, evaporation, and runoff (Adams 1966, Springfield 1972). Mulching may also reduce salinity by reducing evaporation and subsequent salt accumulation at the soil surface (Fanning and Carter 1963, Hamilton 1972). Mulch, fertilizer, gypsum, and various physical amendments enhanced establishment of several shrubs on saline-alkali (EC_e 9.2 dS m^{-1}, SAR 33.1) bentonite mine spoils (Uresk and Yamamoto 1986).

Reclamation of oil well reserve pits is a major concern to land owners, energy firms, and resource management agencies. The objective of this study was to evaluate selected plant materials and mulching for returning these areas to acceptable levels of productivity.

Study Areas

The study was conducted in the western Edwards Plateau resource area on land owned by the University of Texas System in Reagan County, near Big Lake, Texas. The climate is semiarid, with hot summers and cold, dry winters. Annual precipitation averages 43 cm, approximately 78% of which occurs from May to October. Much of the warm-season rainfall occurs from localized convection showers and thunderstorms. The average daily maximum temperature in July is 35.5° C, and the average frost-free period is 229 days (Blum 1977).

Two experiments were established on oil well reserve pits about 10 km east of Big Lake (Ferguson sites) in the spring of 1981, and 2 experiments were established on reserve pits 32 km west of Big Lake (Jackson sites) in the spring of 1982. Soils were Reagan silty clay loams (fine-silty, mixed, thermic family of Ustollic Calciorthids). Dominant grasses on rangeland adjacent to the study sites were buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], burro-

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grass (*Scleropogon brevifolius* Phil.), and tobosa [*Hilaria mutica* (Buckl.) Benth.]. Major forbs included broom snakeweed [*Xanthocephalum sarothrae* (Pursh) Shinners], desertholly (*Perezia nana* Gray), and leatherweed croton [*Croton pottsii* (Klotzsch) Muell. Arg.]. Honey mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.) was the primary woody species at the Ferguson sites, whereas creosotebush [*Larrea tridentata* (DC.) Cov.] and tarbush (*Flourensia cernua* DC.) were the dominate shrubs at the Jackson sites.

Methods

Species evaluated were King Ranch bluestem [*Bothriochloa ischaemum* (L.) Keng], Lehmann lovegrass (*Eragrostis lehmanniana* Nees), kleingrass 'Selection 75' (*Panicum coloratum* L.), alkali sacaton [*Sporobolus airoides* (Torr.) Torr.], kochia [*Kochia scoparia* (L.) Schrad.], and fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.]. Fourwing saltbush seeds were harvested in November 1980 from a native stand at Texon, Texas, 17 km west of Big Lake and dewinged in a modified hammermill (Springfield 1964). Fourwing saltbush seedlings were grown in 4 by 5 by 18-cm polyethylene containers in a peat moss/vermiculite/silty clay loam soil mixture (2:1:1 by volume) in a greenhouse for about 3 months prior to transplanting. Transplants were pruned to 10 cm prior to planting to reduce initial moisture stress. Grass and kochia seeds were purchased from commercial sources.

Each reserve pit was covered 1 month prior to seedbed preparation by the standard procedure with a crawler-tractor, then disked and fenced to exclude livestock, white-tailed deer (*Odocoileus virginiana* Zimmerman), and lagomorphs. Each site was divided into 6 blocks containing 6.1- by 6.1-m plots and the following treatments were randomly assigned within each block:

1. King Ranch bluestem seeded at 3.4 kg pure live seed (P.L.S.)/ha;
2. Kleingrass seeded at 2.2 kg P.L.S./ha;
3. Lehmann lovegrass seeded at 1.1 kg P.L.S./ha;
4. Alkali sacaton seeded at 1.1 kg P.L.S./ha (Jackson sites only);
5. Kochia seeded at 2.2 kg P.L.S./ha;
6. Fourwing saltbush seeded at 13.9 kg P.L.S./ha; and,
7. Fourwing saltbush seedlings transplanted on 0.9-m centers (36 transplants per plot).

Experimental design was a randomized complete block arranged as a split-block with 3 replications. Planting dates were 28 April 1981 at the Ferguson sites and 17 March 1982 at the Jackson sites. Seeds were broadcast onto freshly disced soil with a hand spreader and cultipacked twice. Forage sorghum (Ferguson sites) or wheat straw (Jackson sites) mulch (main plot effect) was applied at 4,500 kg/ha after seeding to half the blocks on each reserve pit. One reserve pit at each location was sprinkler irrigated for 1 to 2 months after planting to facilitate seedling emergence. A total of 5.1 cm of irrigation was applied at the rate of 0.6 cm/hr on 4 dates between 13 May and 28 May 1981 at the Ferguson site, while a total of 18.4 cm was applied on 13 days between 12 May and 9 July 1982 at the Jackson site. The other reserve pit at each location received no irrigation.

Soil samples were collected from 0 to 15-, 15 to 30-, and 30 to 45-cm depths at the time of planting from 12 locations arranged on a grid system within each reserve pit and from adjacent undisturbed areas outside the plots.

Samples were air dried and pulverized to pass a 2-mm sieve and analyzed by the Texas Agricultural Extension Service Soil Testing Laboratory for soluble cations (Ca, Mg, K, Na) and anions (SO_4, Cl), electrical conductivity (EC_e), and pH (Welch et al. 1980) using extracts from the saturated paste (U.S. Salinity Lab. Staff 1954).

Seedlings were counted in 10, equidistantly spaced, 0.25-m^2 quadrats in each plot 2 months after planting. Seedlings were also counted 6 and 16 months after planting at the Ferguson sites, and 7 months after planting at the Jackson sites using the same procedure. Standing crops were estimated 6 and 16 months after plant-

Table 1. Mean soluble cation and anion concentrations (meq L^{-1}), pH, electrical conductivities (dS m^{-1}), and sodium adsorption ratios at 3 depths on oil well reserve pits and adjacent undisturbed areas near Big Lake, Texas.[1]

	Soluble cation				Soluble anions				
Depth	Ca	Mg	K	Na	Cl	SO_4	pH	EC_e	SAR
(cm)	(meq/L)							(dS/m)	
Ferguson Irrigated									
0–15	12 (8)	4 (3)	1 (<1)	14 (14)	13 (11)	14 (2)	8.4 (<1)	3 (<1)	5 (5)
15–30	11 (9)	4 (6)	1 (1)	22 (24)	20 (22)	5 (3)	8.4 (<1)	5 (3)	8 (8)
30–45	19 (17)	10 (14)	1 (2)	44 (62)	61 (102)	20 (20)	8.2 (<1)	7 (5)	9 (10)
Ferguson Dryland									
0–15	17 (13)	6 (6)	1 (<1)	52 (39)	59 (46)	36 (13)	8.4 (<1)	9 (6)	15 (6)
15–30	22 (20)	7 (9)	1 (1)	54 (56)	119 (115)	10 (5)	8.2 (<1)	11 (10)	12 (8)
30–45	23 (18)	8 (8)	2 (3)	75 (93)	92 (137)	7 (4)	8.2 (<1)	11 (11)	16 (17)
Ferguson Undisturbed									
0–15	10 (6)	<1 (<1)	1 (<1)	<1 (<1)	1 (<1)	2 (<1)	8.1 (<1)	1 (<1)	0
15–30	8 (7)	<1 (<1)	<1 (<1)	<1 (<1)	1 (<1)	2 (<1)	8.2 (<1)	1 (<1)	<1 (<1)
30–45	6 (2)	<1 (<1)	<1 (<1)	<1 (<1)	1 (<1)	1 (<1)	8.2 (<1)	1 (<1)	<1 (<1)
Jackson Irrigated									
0–15	138 (47)	43 (12)	2 (2)	229 (75)	884 (385)	26 (27)	7.5 (<1)	93 (56)	69 (23)
15–30	148 (101)	16 (11)	2 (2)	275 (49)	597 (445)	69 (35)	7.6 (<1)	71 (77)	35 (18)
30–45	110 (47)	46 (16)	1 (<1)	290 (28)	484 (136)	32 (13)	7.5 (<1)	113 (148)	33 (7)
Jackson Dryland									
0–15	156 (18)	41 (5)	4 (1)	5125 (2687)	1772 (523)	97 (45)	7.5 (<1)	114 (52)	127 (47)
15–30	110 (20)	19 (3)	2 (1)	917 (343)	1122 (312)	93 (62)	7.5 (<1)	97 (56)	117 (54)
30–45	120 (22)	15 (18)	2 (1)	609 (679)	673 (827)	103 (73)	7.5 (<1)	113 (42)	83 (98)
Jackson Undisturbed									
0–15	8 (3)	1 (<1)	<1 (<1)	1 (<1)	2 (<1)	2 (<1)	8.2 (<1)	1 (<1)	1 (<1)
15–30	8 (1)	1 (<1)	<1 (<1)	2 (<1)	2 (<1)	1 (<1)	8.2 (<1)	1 (<1)	1 (<1)
30–45	6 (<1)	1 (1)	<1 (<1)	1 (<1)	2 (<1)	2 (<1)	8.2 (<1)	1 (<1)	1 (<1)

[1]Values in parentheses are the standard deviations for the respective means.

ing at the Ferguson sites and 7 months after planting at the Jackson sites by harvesting to ground line within 10, equidistantly spaced, 0.25-m^2 quadrats in each plot. Six transplanted fourwing saltbush plants were harvested for estimating standing crop in each plot receiving the transplant treatment. Samples were oven dried at 60° C to a constant weight. Canopy heights of all live fourwing saltbush transplants and 25 fourwing saltbush seedlings in each seeded plot were measured 6 and 16 months after planting at the Ferguson sites.

Treatment effects on stand densities, standing crops, and fourwing saltbush canopy heights were determined using analyses of variance. Means were separated where appropriate with Tukey's *w*-procedure (Steele and Torrie 1960).

Results and Discussion

Drilling fluids severely altered several chemical properties of oil well reserve pit soils (Table 1). The extent of soil contamination varied greatly among locations, reflecting differences in individual drilling operations. Soil chemical properties also varied greatly among samples collected within each reserve pit, indicating that current reserve pit closure procedures do not effectively disperse high chemical concentrations. Concentrations of most soluble cations and anions were greatly increased in reserve pit soils at the Jackson sites, compared to those in adjacent, undisturbed soils, whereas changes at the Ferguson sites were substantial but less dramatic. Sodium and chloride were the predominant ions in reserve pit soils. Soluble salt concentrations in the surface 15 cm at the time of planting averaged 93 and 114 dS m^{-1} on the Jackson irrigated and dryland sites, respectively, and 3 and 9 dS m^{-1} on the Ferguson irrigated and dryland sites, respectively, compared to about 1 dS m^{-1} in adjacent, undisturbed soils. Concentrations of soluble salts at the Ferguson sites increased with depth and concentrations in the surface 15 cm increased 2- to 3-fold during the 16-month period after planting (McFarland 1984). Soluble salt concentrations in soils at the Jackson sites changed little during the year after planting. The salt concentrations at time of planting corresponded to osmotic potentials of -1 to -4 MPa at the Ferguson sites and lower than -11 MPa at the Jackson sites (U.S. Salinity Lab Staff 1954). Sodium adsorption ratios on reserve pit soils were substantially greater than those of undisturbed soils. Soil properties at the Jackson sites were characteristic of saline-alkali soils (U.S. Salinity Lab. Staff 1954).

Ferguson Study Sites

Applied water, 5.1 cm, and rainfall resulted in a total of 30.1 cm of water on the irrigated site, compared to 31.6 cm of rainfall on the dryland site, during the period 1 May through 9 October 1981 (Table 2). Rainfall in May was about 250% of the long-term average for the area. Precipitation during the 1982 growing season was slightly above the long-term average (27.2 cm), totaling 31.1 cm on the irrigated site and 32.9 cm on the dryland site for the period 1 January through 6 August 1982.

Table 2. Monthly precipitation (cm) on oil well reserve pit study sites 10 km east and 32 km west of Big Lake, Texas.

Month	Ferguson Study Sites		Jackson Study Sites	
	Irrigated	Dryland	Irrigated	Dryland
	1981		1982	
January	—[1]	—	0	0
February	—	—	0	0
March	—	—	0.9	0.9
April	—	—	5.7	5.7
May	12.1	12.9	4.4	4.4
June	5.1	5.1	3.7	3.4
July	0	0	0	0
August	1.8	1.9	3.7	4.6
September	1.8	7.4	—	—
October	4.2	4.3	—	—
November	9.6	10.5	—	—
December	0	0	—	—
TOTAL	34.6	42.1	18.4	19.0

[1]Rainfall was not monitored at this time.

Mulching on the irrigated site did not affect seedling establishment (Table 3). Densities of kochia, King Ranch bluestem and kleingrass were greater than those of Lehmann lovegrass and fourwing saltbush 2 months after planting. However, fourwing saltbush seedling densities averaged 2 and 4 plants/m^2 on mulched and unmulched plots, respectively, and were adequate stands. Seed from the Texon population of fourwing saltbush germinated under lower osmotic potentials than did seed from 3 other native populations in western Texas (Potter et al. 1986).

Table 3. Mean densities (plants/m^2) of 5 seeded species 2, 6 and 16 months after planting on April 28, 1981 on an oil well reserve pit 10 km east of Big Lake, Texas (Ferguson Irrigated) as influenced by mulching.[1]

Species	Mulched	No Mulch	Species Means
	(plants/m^2)		
	2 months		
Kochia	78	57	68 a
King Ranch bluestem	56	57	56 a
Lehmann lovegrass	6	4	5 c
Kleingrass	30	33	32 b
Fourwing saltbush	2	4	2 c
	6 months		
Kochia	27	8	18 a
King Ranch bluestem	18	18	18 a
Lehmann lovegrass	1	2	2 b
Kleingrass	16	14	15 a
Fourwing saltbush	1	2	2 b
	16 months		
Kochia	2967	2160	2564 a
King Ranch bluestem	16	12	14 b
Lehmann lovegrass	4	2	3 b
Kleingrass	21	15	18 b
Fourwing saltbush	5	7	6 b

[1]Species means within an evaluation date followed by similar lower case letters are not significantly different at the $P \leq .05$ level according to Tukey's *w*-procedure. Mulching did not affect plant densities.

Densities of most seeded species had decreased 6 months after planting (Table 3). Insufficient root development because of readily available surface soil moisture on the irrigated site, may have contributed to increased seedling mortality (Madison and Hagan 1962). Irrigation may have reduced soluble salt concentrations near the soil surface sufficiently to enhance germination and emergence of the seeded species (Harbert and Berg 1974). However, capillary rise of soluble salts after irrigation ceased, concommitant with decreased rainfall amounts in June, July, and August (Table 2), may have resulted in increased moisture stress and greater seedling mortality (Fanning and Carter 1963). Competition from native forbs on irrigated plots may also have reduced survival of seedlings. Mean forb densities averaged 10 (±1) and 18 (±1) plants/m^2 on irrigated mulched and unmulched plots, respectively, during the first growing season. Competition from annual weeds substantially reduced growth and survival of fourwing saltbush and prostrate summer cypress [*Kochia prostrata* (L.) Shrad.] (Van Epps and McKell 1983).

Kochia densities on the irrigated site increased markedly during the second growing season (Table 3, 16-month evaluation) following seed production in 1981. Subsequent intraspecific competition decreased growth and yields of kochia (Table 4). Fourwing saltbush densities also increased in 1982, apparently from germination of dormant seeds. Dormancy may be an important survival mechanisms during periods of severe moisture stress caused by high salt concentrations in the soil (Shannon 1984). Densities of native forbs

Table 4. Means standing crops (kg/ha) of selected species 6 and 16 months after planting on 28 April 1981 on an oil well reserve pit 10 km east of Big Lake, Texas (Ferguson Irrigated) as influenced by mulching and method of propagation.[1]

Propagation Method/Species	6 months			16 months		
	Mulched	No Mulch	Mean	Mulched	No Mulch	Mean
Seeded						
Kochia	10656	14928	12792 a	7588	10588	9088 a-c
King Ranch bluestem	272	960	616 b	732	264	498 c
Lehmann lovegrass	8	72	40 b	92	172	132 c
Kleingrass	236	1564	900 b	3720	5280	4500 bc
Fourwing saltbush	84	692	388 b	7320	22440	14880 a
Transplanted						
Fourwing saltbush	524	2344	1434 b	9080	18000	13540 ab
Treatment Mean	1963 b	3426 a		4755 b	9457 a	

[1]Species means within a column and treatment means within a row followed by similar lower case letters are not significantly different at the $P \leq .05$ level according to Tukey's *w*-procedure.

were greater on irrigated plots 16 months after planting, averaging 31 and 43 plants/m² on irrigated mulched and unmulched plots, respectively, compared to 2 and 1 plants/m² on dryland mulched and unmulched plots, respectively.

Averaged across all species, mulch significantly decreased standing crops 6 and 16 months after planting on the irrigated site (Table 4). This was attributed to competition from volunteer forage sorghum which established from seed in the mulch and to competition from forbs. Gould et al. (1975) encountered similar problems with mulch while establishing native range plants on coal mine spoils in New Mexico. Incorporation of herbicides for weed control in mulches has been proposed (Springfield 1972), although use of "seed-free" mulching materials would likely be more cost effective.

Standing crops of kochia on the irrigated site were significantly greater than those of the other species 6 months after planting, averaging 12,792 kg/ha (Table 4). The potential for rapid establishment of this annual species on severely disturbed, salt-affected soils in this region has been observed. Transplanted fourwing saltbush tended to have greater first-growing-season standing crops than that in seeded plots, but differences were not significant.

Standing crops of most species on the irrigated site increased during the 1982 growing season (Table 4, 16-month evaluation). Biomass production of seeded and transplanted fourwing saltbush tended to be greater than that of the other species, averaging 14,880 and 13,540 kg/ha, respectively. Canopy heights and standing crops of fourwing saltbush transplants were generally greater than those in plots in which the species established from seed, although differences were not significant. Average canopy heights were 103 (±12) cm for transplants compared to 87 (±7) cm for plants established from seed. Survival of seeded and transplanted fourwing saltbush plants established in the first growing season was 100%. Kleingrass was most productive of the 3 grass species, with standing crops averaging 4,500 kg/ha. Kochia standing crops after 16 months were lower than those in the first growing season. Poor vigor and chlorosis of kochia suggested that available soil nutrients may have been depleted due to heavy biomass production in 1981.

Stand densities on the dryland study site exhibited a significant mulch × species interaction 2, 6, and 16 months after planting (Table 5). Densities of King Ranch bluestem and kleingrass were significantly greater on mulched plots compared to unmulched plots on each evaulation date. A similar trend was observed for fourwing saltbush. Densities of most species had decreased 6 months after planting. Mean densities of competing forb species on dryland plots averaged 1< plant/m² at the end of the first growing season. Kochia densities increased dramatically in the second growing season. In general, densities of the seeded species in most plots were sufficient to develop acceptable stands.

A significant mulch × species interaction for standing crops was observed on both the 6 and 16 month evaluation dates (Table 6).

Table 5. Mean densities (plants/m²) of 5 seeded species 2, 6 and 16 months after planting on 28 April 1981 on an oil well reserve pit 10 km east of Big Lake, Texas (Ferguson Dryland) as influenced by mulching[1].

Species	Mulched	No Mulch
	(plants/m²)	
	2 months	
Kochia	21 a-c	21 a-c
King Ranch bluestem	25 ab	4 c
Lehmann lovegrass	2 c	6 bc
Kleingrass	36 a	2 c
Fourwing saltbush	8 bc	2 c
	6 months	
Kochia	9 a-c	15 bc
King Ranch bluestem	20 ab	3 c
Lehmann lovegrass	1 c	8 bc
Kleingrass	28 a	1 c
Fourwing saltbush	8 bc	1 c
	16 months	
Kochia	2202 a	3880 a
King Ranch bluestem	18 bc	2 d
Lehmann lovegrass	2 d	5 b-d
Kleingrass	22 b	3 cd
Fourwing saltbush	6 b-d	4 cd

[1]Means within an evaluation date followed by similar lower case letters are not significantly different at the $P \leq .05$ level according to Tukey's *w*-procedure.

Table 6. Mean standing crops (kg/ha) of selected species 6 and 16 months after planting 28 April 1981 on an oil well reserve pit 10 km east of Big Lake, Texas (Ferguson Dryland) as influenced by mulching and method of propagation.[1]

Propagation Method/Species	6 months		16 months	
	Mulched	No Mulch	Mulched	No Mulch
	(kg/ha)			
Seeded				
Kochia	5396 b	10396 a	6960 bc	8652 ab
King Ranch bluestem	1424 cd	156 d	1908 c	108 b
Lehmann lovegrass	1 d	248 d	360 c	3932 ab
Kleingrass	4980 bc	96 d	13842 ab	680 b
Fourwing saltbush	2328 b-d	1124 d	17468 ab	16748 ab
Transplanted				
Fourwing saltbush	3892 b-d	2124 b-d	24212 a	20548 a

[1]Means within an evaluation date followed by similar lower case letters are not significantly different at the $P \leq .05$ level according to Tukey's *w*-procedure.

Standing crops of kochia on dryland unmulched plots were greater than those of the other species, averaging 10,396 kg/ha 6 months after planting. Mulching significantly, increased production of kleingrass and similar trends were evident for King Ranch bluestem and fourwing saltbush (seeded and transplanted). Kleingrass tended to produce the most uniform grass stands followed by King Ranch bluestem and Lehmann lovegrass.

Standing crops of most species on the dryland site increased in the second growing season (Table 6, 16-month evaluation). Significant interaction between mulch and species occurred due to the poor response of kochia and Lehmann lovegrass on mulched plots. Growth suppression of some species has been associated with the application of mulch (Stroh and Sundberg 1971, Behmer and McCalla 1963). High rates of mulch application may physically impair establishment of small-seeded species (Bieber 1969). Standing crops of seeded and transplanted fourwing saltbush tended to be greater than those of the other species. Canopy heights of seeded and transplanted fourwing saltbush averaged 91 (±19) and 119 (±11) cm, respectively, and survival of shrubs established by both propagation methods was near 100%.

Jackson Study Sites

Precipitation on the Jackson study sites was only 79% of the long-term average during the first growing season (Table 2). Only 0.9 cm of rainfall was received during March 1982 (49% of long-term average), the month in which the experiments were established. Irrigation water applied from 12 May through 9 July 1982 totaled 18.4 cm. This resulted in a total of 36.8 cm of water on the irrigated site, compared to 19.0 cm of precipitation on the dryland site for the period of 17 March through 16 October 1982.

High concentrations of soluble salts in reserve pit soils at the Jackson sites (Table 1) seriously impaired seedling establishment. Mulching did not improve seedling establishment or standing crops of the seeded species on irrigated (Table 7) or dryland reserve pits. Accelerated decomposition and some wind displacement of mulch occurred on these highly saline sites. Irrigation resulted in limited establishment of the seeded species; however, only 4 species had produced measurable stands on the irrigated site 7 months after planting (Table 7) while no establishment of seeded species occurred on unirrigated plots. Alkali sacaton established the most uniform stands, followed by kleingrass and King Ranch bluestem. An encouraging result was the response of transplanted fourwing saltbush on these severely altered soils. Survival of fourwing saltbush transplants 7 months after planting averaged 30 and 26% on the irrigated and dryland sites, respectively, and standing crops averaged 1,049 and 948 kg/ha, respectively. Fourwing saltbush has been shown to adjust osmotic potentials and maintain positive turgor at plant water potentials lower than −4 MPa (Richardson and McKell 1980). Net photosynthesis has been reported in other species of *Atriplex* at plant water potentials lower than −9 MPa (White 1976).

Table 7. Mean densities (plants/m²) and standing crops (kg/ha) of selected species 7 months after planting on 17 March 1982 on an oil well reserve pit 32 km west of Big Lake, Texas (Jackson Irrigated) as influenced by mulching and method of propagation.[1]

Propagation Method/Species	Plant Density		Standing Crop	
	Mulched	No Mulch	Mulched	No Mulch
	----(plants/m²)---		-----(kg/ha)-----	
Seeded				
Kochia	0	0	0	0
King Ranch bluestem	0	10	0	608
Lehmann lovegrass	0	0	0	0
Kleingrass	0	11	0	200
Alkali sacaton	1	5	19	796
Fourwing saltbush	1	2	39	864
Transplanted				
Fourwing saltbush	—	—	206	1891

[1]Means within each attribute were not significantly different at $P \leq .05$.

Conclusions

Soils from reserve pits should be analyzed to determine levels of factors that might inhibit germination and establishment of seeded species prior to planning and implementation of revegetation projects. The capillary rise of soluble salts within the soil profile which may occur over time should be taken into consideration when interpreting base-line soil analyses and selecting species to be seeded.

Fourwing saltbush appears to be well adapted to soil conditions on recently covered oil well reserve pits. However, rapid establishment of the species on reserve pit soils with extremely high soluble salt concentrations may require transplanting containerized seedlings. Kochia apparently should not be seeded at rates as great as 2.2 kg/PLS/ha on reserve pits unless temporary cover is urgently needed. Planting kochia at very low seeding rates in mixtures with perennial species could be an alternate strategy. Kleingrass and alkali sacaton appear more promising than King Ranch bluestem and Lehmann lovegrass for revegetating oil well reserve pits in west Texas.

Mulching was not critical for establishing broadcast-seeded grasses, kochia, or fourwing saltbush on reserve pit soils with low-to-moderate concentrations of soluble salts. However, the practice may be beneficial in other circumstances. Seed-free mulching material should be used if at all possible.

The costs for fencing and seeding small areas such as oil well reserve pits (approximately 0.5 ha) may be very high relative to current land values and potential productivity of the land. However, resale value of rangeland may be enhanced if barren areas are revegetated. Small plantings of desirable shrubs such as fourwing saltbush could also substantially benefit wildlife populations, and serve as a seed source for dissemination of desirable shrub seeds onto adjacent rangeland.

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