Reprinted from *Journal of Range Management*
Vol. 36, No. 6, November 1983, p. 726-729

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The Initial Growth of Two Range Grasses on Nonfertilized and Fertilized Soils Collected from Creosotebush Communities in the Southwestern United States

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Abstract

A glasshouse study was conducted to determine how nonfertilized and fertilized soils collected in creosotebush [*Larrea tridentata* (DC.) Cov.] communities would influence seedling leaf growth and shoot production of Lehmann lovegrass (*Eragrostis lehmanniana* Nees) and blue panicgrass (*Panicum antidotale* Ritz.). Soils were collected at 3 locations around creosotebush plants: (1) at the crown base (Basal), (2) along the outer canopy edge (Drip), and (3) in areas between plants (Open). Leaf lengths and shoot production were greatest on nonfertilized soils collected at the plant base, intermediate at the canopy edge, and least in open areas. Leaf lengths and shoot production significantly increased on fertilized soils collected in open areas.

The area from South Central California eastward to the Trans-Pecos in Texas and southward from Central Arizona and New Mexico to Central Mexico is a vast region of basins, valleys, and parallel but discontinuous mountain chains (Mabry et al. 1977). Historically, creosotebush [*Larrea tridentata* (DC.) Cov.] occupied rocky upland sites at lower elevations (Gardner 1951, Buffington and Herbel 1965, Mehrhoff 1955), but has recently invaded grassland and mesquite [*Prosopis juliflora* (Schwartz.) DC.] sites (Humphrey 1958, Chew and Chew 1965, York and Dick-Peddie 1969).

It is desirable to replace creosotebush with perennial grasses to reduce erosion, increase infiltration and provide a reliable forage crop for livestock. However, a successful stand of seeded perennial grasses can be expected in only 1 of 10 planting years (Cox et al. 1982). Stand failures have been attributed to precipitation distribution, reduced surface litter, infiltration, competition and possibly allelopathy (Bridges 1941, Glendening 1942, Anderson et al. 1957, Knipe and Herbel 1966, Jordan 1970).

Tiedemann and Klemmedson (1973) and Ryan et al. (1975) have demonstrated the importance of macro and micronutrients on range grass production at mesquite and creosotebush sites in Southeastern Arizona. Tiedemann (1970) showed that perennial grass production under mesquite canopies exceeded that of open areas between plants by 5 times. Soil moisture, soil temperature, and shading between areas under mesquite and open areas were not sufficient to account for the differences (Tiedemann et al. 1971).

On the basis of knowledge gathered on creosotebush and inference from other shrubs, we expect lateral root absorption of soil moisture to be accompanied by absorption of soil nutrients. Nutrients are translocated, incorporated in plant biomass and eventually returned to the soil directly beneath the creosotebush canopy. This process, in time, would result in a depleted nutrient area between plants and an accumulation area under plants. When soil moisture and temperature are ideal, perennial grass seedling growth should be greater under creosotebush canopies and less in open areas between plants.

This study was conducted to determine (1) perennial grass seedling growth on soils collected under creosotebush and in open areas between plants at 5 sites in the Southwestern United States and (2) if a fertilizer complement containing both macro and micronutrients would increase plant growth when added to depleted soils collected at the canopy drip zone or in open areas between plants.

Study Sites and Methods

The study sites are located (1) 24 km north of Carlsbad, N. Mex., along Rocky Arroyo; (2) 26 km south of Las Cruces, N. Mex., and

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This study is a contribution from the Arid Land Ecosystems Improvement Research Unit, Agr. Res. Serv., Agr. Res., USDA, Tucson, Arizona 85719.
Manuscript received September 15, 1982.

east of I-10 near Mesquite, N. Mex.; (3) 20 km east of San Simon, Ariz. and south of I-10 on Cavet Road; (4) 40 km south of Tucson, Ariz., in Pasture 15 on the Santa Rita Experimental Range (SRER); and (5) 16 km east of Barstow, Calif., and south of I-10 near Daggett, Calif.

The Carlsbad site is near the Pecos River on a narrow alluvial fan with 1 to 3% slopes on a west-east axis; soils are Ector stony loam-loamy, skeletal carbonatic, thermic Lithic Calciustolls (Chugg et a. 1971). Mesquite is above the Rio Grande flood plain and below a series of arroyo-dissected rocky hillsides with 1 to 5% slopes on a east-west axis; soils are Yturbide loamy sand, mixed thermic Typic Torripsamments (personal communications USDA-SCS). San Simon is on a large alluvial plain above active arroyos with 4 to 6% slopes on a north-south axis; soils are Tres Hermonos gravelly loam, fine loamy, mixed, thermic Typic Haplargids (Vogt 1980). Santa Rita Experimental Range is on a terrace above the Santa Cruz River with 2 to 6% slopes on a east-west axis; soils are an Anthony variant, loamy sand, mixed, calcareous, thermic Typic Torrifluvents (Richardson et al. 1979). Daggett is on a broad alluvial fan with 1 to 2% slopes on a south-north axis; soils are Cajon gravelly sand, mixed, thermic Typic Torripsamments (personal communications USDA-SCS).

We arbitrarily selected 10 creosotebush plants of approximately the same height and canopy area at each study site. A sample of soil from the 0 to 15-cm depth was taken at 3 locations around each creosotebush: (1) at the crown base (Basal), (2) along the outer canopy edge (Drip), and (3) in areas between plants (Open). Equal soil volumes were collected at each location in the cardinal directions around each plant. Soils from each location (Basal, Drip, and Open), along each cardinal direction, from the 10 plants at each site were composited and stored in plastic bags.

Because of the distance between study sites and limitations of greenhouse space, soils were collected at Mesquite, San Simon, and SRER in fall 1981; and collected at SRER, Carlsbad, and Daggett in spring 1980. Differences in plant growth based on season were anticipated. Therefore, soils from the SRER were collected twice and included in the fall and spring experiments.

Soil Analysis

One-kilogram soil samples from each composite soil collection (3 total) within each community (5 total) were oven-dried at 40°C for 120 h, and passed through a 2-mm sieve. Triplicate samples from each composite were analyzed for nitrates (Jackson 1958).

Greenhouse Procedure

The 3 composite soil collections from each community plus the spring repeat from the SRER constituted 18 composite soil samples. Each sample was individually mixed to simulate mechanical soil disturbance, screened to 2 mm, and divided into 16 lots each weighing 1.6 kg. Lots were placed into 15-cm tapered plastic pots. Pots 1 to 8 were seeded with 50 seeds of Lehmann lovegrass (A-68) and pots 9 to 16 were seeded with 50 seeds of blue panicgrass (A-130). The small-seeded Lehmann lovegrass was planted at 0.1 cm and the large-seeded blue panicgrass planted at 0.5 cm.

Odd-numbered pots received no fertilizers. Even-numbered pots received a single 10 ml aqueous solution containing 300 mg $Ca(H_2PO_4)_2 \cdot H_2O$ and 1 mg $(NH_4)_6Mo_7O_{24} \cdot H_2O$ was added after seeding to even-numbered pots. A 10-ml aqueous solution containing: (1) 520 mg NH_4NO_{33}, (2) 80 mg $MgSO_4 \cdot 7H_2O$, (3) 80 mg K_2SO_4, (4) 17.50 mg FeEDDHA, (5) 2.00 mg $NaB_4O_7 \cdot 10H_2O$, (6) 1.75 mg MnEDTA, (7) 0.50 mg ZnEDTA, and (8) 0.25 mg CuEDTA was added weekly to even-numbered pots for 5 weeks. All pots were watered daily with 100 mg of distilled water. Excess water was collected in dishes under each pot and readded to the pot.

Relative humidity in the greenhouse varied from 45 to 55% and photoperiod was constant at 15 h. Temperature ranged from 29 to 32°C in the fall and 30 to 35°C in the spring.

Seedlings were thinned to 20 per pot at 1 week, 10 at 2 weeks, and 5 at 3 weeks to reduce competition. Thinned seedlings were readded to the soil surface to reduce nutrient losses.

Leaf heights were measured to the nearest 0.5 cm from the soil surface to the extended leaf tip for the 5 plants at 6 weeks after emergence. Shoots were clipped at the soil surface, dried at 40°C for 48 h, and weighed to the nearest 0.1 g.

A stratified randomized block design was used to determine pot arrangement in the greenhouse. Analysis of variance was used for the statistical evaluation of data. Tukey's (hsd)-w-procedure was used for comparison of treatment means (Steel and Torrie 1960). There were 2 experiments and each was analyzed separately.

Results and Discussion

Mean creosotebush heights ranged between 1.0 and 1.5 m and canopy areas between 2.0 and 3.0 m² at Mesquite, SRER, and Daggett. Mean heights were less than 0.5 m and canopy areas less 0.5 m² at Carlsbad and San Simon. Hummocks, or areas under creosotebush where litter accumulates, extended 0.1 m from the plant base at Carlsbad, 0.4 m at San Simon, and between 1.0 and 1.5 m at the remaining sites.

Nitrate accumulations (Table 1) were greatest in Basal, Drip, and Open soils collected at Carlsbad and Daggett, and significantly less in soils collected at the remaining sites. Once creosotebush dominates a site, open areas between plants actively erode (Hallmark and Allen 1975), windblown soil and organic matter accumulate (Muller 1953), and nitrate levels under the plant exceed levels found in open areas between plants (Garcia-Moya and McKell 1970, Romney et al. 1980). Nitrates decreased with distance from the plant base at all sites. However, similarities in Basal and Drip or Drip and Open collections are site specific and likely influenced by plant density, height, and climate.

Table 1. Nitrates (ppm) in surface soils collected at 3 locations around creosotebush plants at 5 sites.

Soil source	Nitrates[1]		
	Basal	Drip	Open
Mesquite	18.42^b	2.33^d	0.42^d
San Simon	4.33^c	2.60^d	0.08^e
SRER	6.25^{bc}	2.67^d	1.25^d
Carlsbad	45.42^d	16.80^d	20.17^b
Daggett	52.17^a	51.28^a	25.83^b
$\bar{X}$	25.32	15.14	9.55

[1]Means followed by the same superscript are not significantly different ($P \leq 0.05$) according to Tukey's (hsd) test.

Lehmann lovegrass seedlings began to emerge 6 days after planting and blue panicgrass seedlings at 3 days. Emergence was complete after 14 days for both species.

Lehmann Lovegrass

Lehmann lovegrass leaf lengths varied between 0.5 and 1.0 cm at week 1, 3.5 to 15.5 cm at week 3, and 40 to 65.5 cm at week 6. Small, stunted plants grew on nonfertilized Open soil collections and occasionally on Drip collections. Greenhouse temperature differences during the fall and spring had an effect on Lehmann lovegrass leaf growth (Table 2). Leaves of plants grown in soils collected at SRER were one-third to one-half greater than on soils collected in fall. Although absolute numbers widely separated, trends in leaf growth were similar on SRER soils for both experiments.

Lehmann lovegrass leaf lengths on nonfertilized soil were influenced by soil source and location (Table 2). Nitrate accumulations (Table 1) were greatest in Carlsbad and Daggett soils, and leaf lengths were greatest. Nitrate accumulations were least on Open soils collected at Mesquite, San Simon, and SRER, and leaf lengths were correspondingly low.

The addition of fertilizer significantly increased leaf lengths on Drip and Open soils, with the exception of soils collected at Carlsbad and Daggett (Table 2). Mean leaf lengths were 27, 40, and 66%

Table 2. Leaf lengths (cm) of Lehmann lovegrass seedlings grown for 6 weeks on nonfertilized and fertilized soils collected in fall and spring. Soils were collected at 3 locations in 5 creosotebush communities.

		Nonfertilized			Fertilized		
Collection season[1]	Soil source	Basal	Drip	Open	Basal	Drip	Open
Fall	Mesquite	26.7^{b}	20.7^{c}	11.2^{de}	38.7^{a}	30.7^{ab}	27.2^{b}
	San Simon	20.5^{bc}	12.0^{c}	5.2^{e}	27.7^{b}	27.5^{b}	18.3^{c}
	SRER	23.2^{bc}	15.0^{d}	7.2^{e}	32.5^{a}	27.2^{b}	25.2^{b}
	$\overline{X}$	24.3	17.3	6.8	30.0	24.7	
Spring	SRER	34.0^{cd}	27.6^{d}	15.4^{e}	43.4^{b}	36.1^{c}	38.4^{c}
	Carlsbad	46.7^{b}	35.6^{c}	33.5^{cd}	47.2^{b}	45.2^{b}	45.5^{b}
	Daggett	60.7^{a}	52.9^{a}	24.1^{d}	61.7^{a}	56.6^{a}	46.5^{a}
	$\overline{X}$	47.1	38.7	24.3	50.8	46.0	43.5

[1]Means for individual collection seasons followed by the same superscript are not significantly different ($P\leq0.05$) according to Tukey's (hsd) test.

Table 3. Shoot production (g) of Lehmann lovegrass seedlings grown for 6 weeks on nonfertilized and fertilized soils collected in fall and spring. Soils were collected at 3 locations in 5 creosotebush communities.

		Nonfertilized			Fertilized		
Collection season[1]	Soil source	Basal	Drip	Open	Basal	Drip	Open
Fall	Mesquite	2.4^{a}	1.7^{b}	1.7^{b}	3.3^{a}	2.8^{a}	2.3^{a}
	San Simon	2.0^{a}	1.1^{b}	1.3^{b}	2.3^{a}	2.1^{ab}	1.4^{b}
	SRER	3.0^{a}	2.4^{a}	1.8^{b}	3.0^{a}	3.0^{a}	2.9^{a}
	$\overline{X}$	2.5	1.7	1.6	2.9	2.6	2.2
Spring	SRER	1.5^{c}	1.1^{c}	0.3^{d}	3.3^{ab}	2.8^{b}	2.1^{b}
	Carlsbad	3.7^{a}	2.1^{bc}	1.4^{c}	4.2^{a}	4.0^{a}	2.8^{b}
	Daggett	4.6^{a}	3.6^{a}	1.4^{c}	4.7^{a}	4.3^{a}	3.1^{ab}
	$\overline{X}$	3.3	2.3	1.0	4.1	3.7	2.7

[1]Means for individual collection seasons followed by the same superscripts are not significantly different ($P\leq0.05$) according to Tukey's (hsd) test.

Table 4. Leaf lengths (cm) of blue panicgrass seedlings grown for 6 weeks on nonfertilized and fertilized soils collected in fall and spring. Soils were collected at 3 locations in 5 creosotebush communities.

		Nonfertilized			Fertilized		
Collection season[1]	Soil source	Basal	Drip	Open	Basal	Drip	Open
Fall	Mesquite	18.5^{bc}	16.0^{c}	11.0^{cd}	23.7^{b}c	20.5^{b}	21.5^{b}
	San Simon	23.3^{b}	10.7^{d}	7.0^{d}	32.5^{a}	17.2^{c}	16.0^{c}
	SRER	15.5^{c}d	8.2^{d}	6.0^{d}	21.5^{b}	17.5^{c}	17.2^{c}
	$\overline{X}$	19.2	12.5	7.3	25.3	18.8	17.9
Spring	SRER	16.9^{d}	12.9^{d}	8.2^{e}	23.4^{c}	20.0^{cd}	17.1^{d}
	Carlsbad	20.9^{cd}	18.2^{cd}	14.0^{d}	28.6^{bc}	25.0^{c}	23.0^{c}
	Daggett	45.9^{a}	32.4^{b}	11.1^{d}	48.1^{a}	38.4^{ab}	20.5^{c}
	$\overline{X}$	27.9	23.2	11.1	33.4	25.8	20.2

[1]Means for individual collection seasons followed by the same superscripts are not significantly different ($P\leq0.05$) according to Tukey's (hsd) test.

Table 5. Shoot production (g) of blue panicgrass seedlings grown for 6 weeks on nonfertilized and fertilized soils collected in fall and spring. Soils were collected at 3 locations in 5 creosotebush communities.

		Nonfertilized			Fertilized		
Collection season[1]	Soil source	Basal	Drip	Open	Basal	Drip	Open
Fall	Mesquite	1.3^{bc}	1.1^{c}	1.1^{c}	2.6^{a}	2.3^{a}	2.3^{a}
	San Simon	0.8^{d}	0.4^{d}	0.6^{d}	1.9^{ab}	1.6^{b}	1.3^{bc}
	SRER	1.4^{c}	1.0^{c}	0.8^{d}	3.3^{a}	2.6^{a}	2.8^{a}
	$\overline{X}$	1.2	0.8	0.8	2.6	2.2	2.1
Spring	SRER	1.6^{de}	1.4^{e}	1.2^{e}	3.3^{cd}	3.2^{cd}	2.3^{d}
	Carlsbad	2.7^{d}	1.8^{d}	1.3^{e}	4.1^{bd}	3.7^{c}	3.4^{c}
	Daggett	6.9^{a}	4.2^{bc}	1.5^{de}	7.3^{a}	5.8^{ab}	2.8^{d}
	$\overline{X}$	3.7	2.5	1.3	4.9	4.2	2.8

[1]Means for individual collection seasons followed by the same superscripts are not significantly different ($P\leq0.05$) according to Tukey's (hsd) test.

greater, respectively, on fertilized Basal, Drip, and Open soils collected at Mesquite, San Simon, and SRER (fall and spring) than on nonfertilized soils.

Accumulated nitrates (Table 1) and increases in leaf lengths (Table 2) are reflected in shoot production increases on nonfertilized soils (Table 3). Fertilization of Basal soils generally increased shoot production, but a significant incease occurred only on the SRER spring collection. Fertilization had a significant effect on shoot production on Open soils; with the exception of San Simon.

Collection season means suggest that nutrient additions will overcome reductions in shoot production; however, deviations do occur among sites.

Blue Panicgrass

Blue panicgrass leaf lengths varied between 3.0 to 5.0 cm at week 1, 5.5 to 54.5 cm at week 3, and were unchanged between weeks 3 and 6. Stunted and chlorotic plants grew on nonfertilized Open and Drip soil collections. Greenhouse temperature differences during fall and spring on SRER soils had a minor effect on blue panicgrass leaf lengths (Table 4).

Leaf lengths on nonfertilized soils were greatest on Basal, intermediate on Drip, and least on Open, but differences were not always significant (Table 4). Fertilization significantly increased leaf lengths on all Open soil collections. Mean leaf lengths were 27, 37, and 55% greater, respectively, on fertilized Basal, Drip, and Open soils collected at Mesquite, San Simon, and SRER (fall and spring) than on nonfertilized soils. Fertilization had a marginal effect on plants grown in Basal and in Drip soils collected at Carlsbad and Daggett.

Blue panicgrass shoot production (Table 5) is generally related to leaf lengths (Table 4) and accumulated nitrates (Table 1) on nonfertilized soils; with the exception of Basal soils collected at San Simon. Nonfertilized plants grown on Basal soils from San Simon were not stunted, but chlorotic and prostrate between weeks 4 and 6. Shoot production under these conditions was not related to leaf lengths. Plants grown on fertilized soils at San Simon and the remaining sites were neither chlorotic nor prostrate, but were stunted on Open soils collected at San Simon.

Shoot production was similar on fertilized Basal, Drip, and Open soil collections made in fall (Table 5). A similar trend was apparent on soil collections made in spring but increases were not significant at Daggett.

Conclusions

Creosotebush and other shrubs in arid regions accumulate nutrients under the canopy at the expense of open areas between plants (Tiedemann and Klemmedson 1973, Romney et al. 1980). If germination occurs, perennial grasses seeded under the plant canopy have a greater probability of becoming established than those seeded in open areas between shrubs.

The stunted appearance of Lehmann lovegrass and chlorotic appearance of blue panicgrass on soils collected from open areas between creosotebush plants and adequate soil moisture implies that even if seeds did germinate, the seedling would probably not survive. The lack of chloroses and increased shoot production with fertilization on Drip and Open soils indicates that seedling establishment should increase because of a more favorable nutrient regime (Tiedemann and Klemmedson 1973).

The difficulty associated with perennial grass establishment in existing creosotebush stands has been attributed to a growth inhibitor produced by creosotebush. Our results suggest that nutrient limitations have a greater impact on seedling growth and eventual establishment than a possible inhibitor.

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