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# Soil Properties in Creosotebush Communities and their Relative Effects on the Growth of Seeded Range Grasses[1]

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## ABSTRACT

**Soils were collected to 15 cm along the four cardinal directions at three locations around 10 creosotebush [*Larrea tridentata* (DC.) Cov.] plants at five sites in the southwestern United States. The sampling locations were: (i) at the canopy center, (ii) along the outer canopy edge, and (iii) in open areas between plant canopies. A portion of the soil from each sampling location was analyzed for particle size distribution, pH, EC, $CaCO_3$, Ca, K, Na, Mg, $NO_3^-$-N, organic C, available P, and Mn. The remaining soil from each sampling location was seeded with either Lehmann lovegrass (*Eragrostis lehmanniana* Nees) or blue panicgrass (*Panicum antidotale* Retz.). Grass seeds were germinated and grown for 42 d in a greenhouse. Nitrate was significantly ($\alpha = 0.05$) lower in open areas between creosotebush canopies than near the shrub canopy center at all sites. Grass seedling growth decreased as the distance from the canopy center increased and seedling growth was highly correlated with nitrate concentrations. Spatial distribution patterns for the other measured soil properties did not occur in a consistent fashion across all sampled sites. The action of mechanical tillage to limit creosotebush competition, and corresponding dilution of $NO_3^-$-N in the soil volume, may reduce the probability of establishing perennial grasses.**

***Additional Index Words:*** **nitrate-N, creosotebush, Lehmann lovegrass, blue panicgrass, soil-plant nutrient relationships.**

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WOODY SHRUBS dominate over 200 million ha of land in the United States (2). In the deserts of the southwestern United States creosotebush [*Larrea tridentata* (DC.) Cov.] dominates approximately 20 million ha (8) and has recently invaded the semidesert grasslands (3, 9, 23).

Often it is desirable to replace creosotebush with perennial grasses in order to reduce soil erosion, increase infiltration, and provide forage for domestic livestock (1, 13). Creosotebush management has consisted of mechanical tillage and seeding perennial grasses for the past 90 years (4). However, the establishment of perennial grasses are seldom successful and treated areas are reinvaded by creosotebush or other annual grasses and forbs.

Since creosotebush is the dominant vegetation component, it is important to know how the distribution of soil particles and nutrients near the soil surface are influenced by plant canopy, and how distribution influences the initial growth of range grasses. The purpose of this study was to: (i) determine if creosotebush canopy influences the distribution of soil physical and chemical properties, and (ii) determine how soil properties influence the initial growth of two commonly seeded range grasses.

## METHODS

### Study Sites

Five sites were selected along an east-west line between southeastern New Mexico and southern California. Sites were located (i) 24 km north of Carlsbad, NM, (ii) 26 km south of Las Cruces, NM, (iii) 20 km east of San Simon, AZ, (iv) 40 km south of Tucson, AZ, and (v) 4 km south of Barstow, CA.

Elevation, precipitation, temperature, and soil classification are presented in Table 1. Elevation is greatest at San Simon and Las Cruces, intermediate at Carlsbad and Tucson, and least at Barstow. Precipitation distribution is approximately 65% in summer, 35% in winter, and freezing temperatures are common in winter and spring at Carlsbad, Las Cruces, and San Simon. Precipitation distribution is approximately 60% in summer and 40% in winter at Tucson, and 34% in summer and 66% in winter at Barstow. Freezing temperatures are not common at Tucson and Barstow, but do occur in January and February (7, 12). Slopes range from 2 to 4% with aspects of west and northwest.

Creosotebush was the predominant shrub species at all sites and its densities were greatest at Tucson and Las Cruces, intermediate at San Simon and Carlsbad, and least at Barstow (Table 2). Total above-ground creosotebush biomass was greatest at Tucson, 43% less at Las Cruces, and 72 and 79% less at San Simon and Barstow, respectively, and least at Carlsbad. Mesquite (*Prosopis* spp.) and cactus (*Opuntia* spp.) were present at Carlsbad, Las Cruces, San Simon, and Tucson; *Zinnia* spp. were present at Tucson and Barstow. Perennial grasses were the predominant understory plants only at Carlsbad.

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Table 1—Site characteristics and soil classification at five creosotebush sites.

| Sites | Elevation | Precipitation | | Temperature | | Soil series | Soil family classification† |
|---|---|---|---|---|---|---|---|
| | | Summer | Winter | Max. | Min. | | |
| | m | mm | | °C | | | |
| Carlsbad | 970 | 124 | 88 | 26 | 9 | Ector | Loamy-skeletal, carbonatic, thermic, Lithic Calciustolls |
| Las Cruces | 1250 | 132 | 72 | 25 | 6 | Yturbide | Mixed, thermic, Typic Torripsamments |
| San Simon | 1260 | 131 | 69 | 26 | 8 | Tres Hermanos | Fine-loamy, mixed, thermic, Typic Haplargids |
| Tucson | 980 | 196 | 134 | 28 | 12 | Anthony | Coarse-loamy, mixed (calcareous), thermic, Typic Torrifluvents |
| Barstow | 790 | 29 | 60 | 27 | 11 | Cajon | Mixed, thermic, Typic Torripsamments |

† Family classification (Soil Survey Staff, 1975).

## Soil Sampling and Analyses

Ten typical creosotebush plants of approximately the same height and canopy area were selected at each site. Surface soils to 15 cm were collected along the four cardinal directions at three locations around each plant. The sampling locations were: (i) at the canopy center, (ii) along the outer canopy edge, and (iii) in open areas between plant canopies. Approximately 0.5 kg of soil was collected at each sampling point in January 1982. Soil collections from the four directions around each plant were composited into three location collections (canopy center, canopy edge, and between canopies). There was a total of 15 composite soil collections for the five sites. Soils were air dried, passed through a 2-mm sieve, and thoroughly mixed.

A soil sample was collected from each composite and three subsamples were analyzed for particle size distribution (6), pH, EC (saturated paste extract), $CaCO_3$ (19), ammonium acetate soluble cations including Ca, K, Na and Mg, $NO_3^-$-N and organic C (10), available P (21), and DTPA extractable Mn (14). An analysis of variance was performed with sampling positions and sites as factors. When significant differences were indicated, means were separated using Duncan's Multiple Range Test (17).

## Greenhouse Studies

The remainder of each composite soil sample was divided into 8 lots, each weighing 1.6 kg. Lots were placed into tapered plastic pots with a 15-cm diam. Pots 1 to 4 were sown with 50 Lehmann lovegrass (*Eragrostis lehmanniana* Nees) seeds and pots 5 to 8 with 50 blue panicgrass (*Panicum antidotale* Retz.) seeds. Pots were placed in a completely random design with 4 blocks in a greenhouse. Greenhouse temperatures ranged from 25 to 35°C, humidity from 55 to 65%, day length from 9.5 to 10.0 h, and no supplemental light was applied.

Pots were watered daily with 100 mL of distilled water, and excess water was collected in a plastic dish under each pot and readded to the pot. Grass seedlings were thinned to 20 per pot at 7 d, 10 per pot at 14 d, and 5 per pot at 21 d after planting.

Mean leaf height from the media surface to the extended leaf tip was measured in each pot at 42 d. After leaves were measured the shoots were clipped at the media surface, and roots were washed from the media. Plant material was dried at 40°C for 48 h.

An analysis of variance was performed with either plant height or pot biomass (roots plus shoots) and sampling position as factors. When significant differences were indicated, means were separated using Duncan's Multiple Range Test (17). Correlation analysis was used to assess the relationships between either mean plant heights or mean pot biomass ($N$ = 15) and sampling position $NO_3^-$-N across all sites ($N$ = 15).

Table 2—The density and above-ground biomass of creosotebush at five study sites.

| Sites | Density | Above-ground biomass |
|---|---|---|
| | plants ha$^{-1}$ | kg ha$^{-1}$ |
| Carlsbad | 1120 | 130 |
| Las Cruces | 2100 | 3370 |
| San Simon | 1950 | 1625 |
| Tucson | 2250 | 5890 |
| Barstow | 550 | 1230 |

# RESULTS AND DISCUSSION

## Soil Properties

Surface soils were generally coarse-textured, nonsaline, alkaline, and calcareous at the five sites. The influence of creosotebush canopy on the distribution of most soil physical and chemical properties was either not significant or inconsistent between the three canopy positions among sites (Tables 3 and 4). Only $NO_3^-$-N was significantly ($\alpha$ = 0.05) different between the shrub canopy center and open areas between plants at all sites. This spatial pattern of N distribution has been documented in mesquite stands (2, 18, 20) and creosotebush stands (5).

We expect lateral root absorption of soil moisture by creosotebush to be accompanied by absorption of soil nutrients. Nutrients are translocated, incorporated in above-ground biomass and eventually returned to the soil surface directly beneath the shrub canopy (18, 20). This process, in time, would result in a depleted nutrient area between plants and an accumulation area under plants. Therefore, trends in nutrient accumulation with respect to sampling locations were expected at all sites. Such trends were not evident, with the exception of $NO_3^-$-N. Apparently shallow rooted desert plants such as creosotebush either do not harvest large quantities of nutrients from open areas between plants or most nutrients are stored below ground rather than being translocated and incorporated into above-ground plant biomass.

Soil particles and organic matter often accumulate as mounds or dunes under the canopies of perennial desert shrubs (20). We observed soil mounds under creosotebush plants at Las Cruces, San Simon, Tucson, and Barstow. Since only $NO_3^-$-N changes consistently with distance from the shrub base, we suspect that: (i) $NO_3^-$-N concentrations under the canopy are primarily due to above-ground litter-fall rather than nitrification of dead roots, and (ii) the $NO_3^-$-N concentration gradient is directly related to the shrub canopy which reduces raindrop impact and soil erosion under the canopy but not in open areas between canopies.

Nitrate concentrations were expectedly high in the Calciustoll sampled at Carlsbad, but unexpectedly high in the Torripsamment at Barstow (Table 4). These high

Table 3—Particle size distribution at five creosotebush sites.

| Sites | Sand | | | | Silt | | | | Clay | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C† | E | B | $\overline{X}$ | C | E | B | $\overline{X}$ | C | E | B | $\overline{X}$ |
| | % | | | | | | | | | | | |
| Carlsbad | 79.3 | 82.3 | 83.3 | 81.6 | 11.3 | 13.3 | 13.2 | 12.6 | 9.4 | 4.4 | 3.5 | 5.8 |
| Las Cruces | 93.6 | 90.3 | 94.6 | 92.8 | 3.9 | 4.6 | 0.2 | 2.9 | 2.5 | 5.1 | 5.2 | 4.3 |
| San Simon | 84.0 | 83.0 | 82.6 | 83.2 | 10.6 | 11.9 | 10.3 | 10.9 | 5.4 | 5.1 | 7.1 | 5.9 |
| Tucson | 93.1 | 92.5 | 89.2 | 91.6 | 5.1 | 5.8 | 8.0 | 6.3 | 1.8 | 1.7 | 2.8 | 2.1 |
| Barstow | 84.2 | 83.2 | 91.2 | 86.2 | 9.8 | 10.1 | 7.1 | 9.0 | 6.0 | 6.7 | 1.7 | 4.8 |
| $\overline{X}$ | 86.8 | 86.3 | 88.2 | | 8.1 | 9.1 | 7.8 | | 5.0 | 4.6 | 4.1 | |

† Sampling positions: C = canopy center; E = canopy edge; B = between canopies. $\overline{X}$ = mean.

$NO_3^-$-N accumulations under the canopy suggest that nitrification proceeds rapidly after litter-fall, but leaching and denitrification are limited by precipitation and temperature (20) at Barstow. Nitrate near the soil surface is probably cycled by winter annuals which accumulate it in winter and then released it in summer.

## Seedling Grass Growth as a Function of Soil $NO_3^-$-N

Typically, desert soils have low $NO_3^-$-N concentrations (15) which can be expected to limit plant growth (22) when water is abundant. Heights of Lehmann lovegrass seedlings varied from 5 to 60 cm and total plant biomass from 2 to 6 g pot$^{-1}$ across sites and sampling positions (Table 5). Heights of blue panicgrass seedlings varied from 7 to 46 cm and total plant biomass from 1 to 11 g pot$^{-1}$ (Table 6). Seedling heights and plant biomass for the two grasses were greatest on soils collected under creosotebush canopies, and the foliage was dark green. Seedlings were stunted, the foliage was yellow, and the heights and total plant biomass were significantly ($\alpha$ = 0.05) less on soils collected from open areas between canopies.

Table 5—Mean Lehmann lovegrass heights and total plant mass (roots plus shoots) after 42 d of growth on soils collected at five creosotebush sites.

| Sites | C† | E | B | $\overline{X}$ |
|---|---|---|---|---|
| | Mean height, cm | | | |
| Carlsbad | 49 | 36 | 33 | 39.3b‡ |
| Las Cruces | 27 | 21 | 11 | 19.7cd |
| San Simon | 20 | 12 | 5 | 12.3d |
| Tucson | 40 | 31 | 10 | 27.0c |
| Barstow | 60 | 53 | 24 | 45.7a |
| $\overline{X}$ | 39.2a§ | 30.6ab | 16.6b | |
| | Mean total plant mass, g pot$^{-1}$ | | | |
| Carlsbad | 5 | 5 | 3 | 4.3ab |
| Las Cruces | 4 | 6 | 2 | 4.0ab |
| San Simon | 3 | 3 | 2 | 2.7b |
| Tucson | 6 | 4 | 2 | 4.0ab |
| Barstow | 6 | 6 | 3 | 5.0a |
| $\overline{X}$ | 4.8a | 4.8a | 2.4b | |

† Sampling positions: C = canopy center; E = canopy edge; B = between canopies. $\overline{X}$ = mean.
‡ Means within columns for each measurement followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.
§ Means within rows for each measurement followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.

Correlations comparing soil sampling location $NO_3^-$-N and either seedling height or total plant biomass varied from $r$ = 0.64 to 0.92 across the five sites ($N$ = 15). As soil $NO_3^-$-N decreased with distance from the canopy center the seedling heights of Lehmann lovegrass ($r$ = 0.92; $\alpha$ = 0.05) and blue panicgrass ($r$ = 0.85; $\alpha$ = 0.05) significantly decreased. Soil $NO_3^-$-N and total seedling biomass of blue panicgrass significantly ($r$ = 0.81; $\alpha$ = 0.05) decreased with distance from the canopy center. The same trend oc-

Table 4—Chemical properties at five creosotebush sites.

| Site | P | | | | Mn | | | | pH | | | | Organic C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C† | E | B | $\overline{X}$ | C | E | B | $\overline{X}$ | C | E | B | $\overline{X}$ | C | E | B | $\overline{X}$ |
| | mg kg$^{-1}$ | | | | | | | | | | | | % | | | |
| Carlsbad | 30.4 | 30.5 | 31.8 | 30.9a‡ | 18.6 | 22.0 | 24.1 | 21.6a | 7.8 | 7.8 | 7.3 | 7.6a | 2.3 | 1.9 | 2.3 | 2.2a |
| Las Cruces | 15.4 | 14.6 | 12.1 | 19.3b | 7.1 | 3.8 | 10.9 | 5.7b | 7.8 | 8.1 | 8.0 | 8.0a | 0.5 | 0.3 | 0.5 | 0.7b |
| San Simon | 27.5 | 25.5 | 25.5 | 26.2a | 21.6 | 9.4 | 3.5 | 11.5ab | 7.9 | 8.0 | 8.0 | 8.0a | 1.8 | 1.0 | 0.8 | 1.2ab |
| Tucson | 20.2 | 19.5 | 18.3 | 14.0b | 5.6 | 6.1 | 5.4 | 7.3b | 7.9 | 8.3 | 8.0 | 8.1a | 0.9 | 0.7 | 0.5 | 0.4b |
| Barstow | 28.3 | 29.3 | 25.6 | 27.7a | 22.0 | 16.4 | 6.9 | 15.1ab | 7.6 | 7.6 | 7.8 | 7.7a | 1.3 | 1.4 | 0.6 | 1.1ab |
| $\overline{X}$ | 24.4a§ | 24.0a | 22.7a | | 15.0a | 11.5a | 10.2a | | 7.8a | 8.0a | 7.8a | | 1.4a | 1.1a | 0.9a | |
| | $CaCO_3$ | | | | $NO_3^-$-N | | | | $Na^+$ | | | | $K^+$ | | | |
| | % | | | | cmol kg$^{-1}$ | | | | | | | | | | | |
| Carlsbad | 17.2 | 17.2 | 17.1 | 17.2a | 45.4 | 16.8 | 20.2 | 27.5b | 1.0 | 2.0 | 1.0 | 1.3a | 14.0 | 13.0 | 14.0 | 13.7a |
| Las Cruces | 1.2 | 2.0 | 1.4 | 1.5b | 18.4 | 2.3 | 0.4 | 7.0c | 1.0 | 0.4 | 0.4 | 0.6a | 8.0 | 4.0 | 10.0 | 4.3b |
| San Simon | 3.4 | 3.4 | 3.2 | 3.3b | 4.3 | 2.6 | 0.8 | 2.6c | 1.0 | 1.0 | 7.0 | 3.0a | 12.0 | 11.0 | 10.0 | 11.0a |
| Tucson | 15.8 | 15.6 | 15.6 | 15.7a | 6.2 | 2.6 | 1.2 | 3.3c | 4.0 | 1.0 | 1.0 | 2.0a | 6.0 | 4.0 | 3.0 | 7.3b |
| Barstow | 1.5 | 1.1 | 1.7 | 1.4b | 52.2 | 51.3 | 25.8 | 43.1a | 6.0 | 3.0 | 1.0 | 3.3a | 19.0 | 13.0 | 5.0 | 12.0a |
| $\overline{X}$ | 7.8a | 7.9a | 7.8a | | 25.3a | 14.8b | 10.0b | | 2.6a | 1.5a | 2.1a | | 11.8a | 9.0a | 8.4a | |
| | $Ca^{2+}$ | | | | $Mg^{2+}$ | | | | EC | | | | | | | |
| | cmol kg$^{-1}$ | | | | | | | | dS m$^{-1}$ | | | | | | | |
| Carlsbad | 10.1 | 10.0 | 9.7 | 10.1b | 2.9 | 2.6 | 2.9 | 2.8a | 1.7 | 1.7 | 1.4 | 1.6a | | | | |
| Las Cruces | 18.8 | 5.6 | 15.0 | 13.2b | 1.2 | 1.3 | 1.3 | 1.3a | 1.3 | 0.9 | 0.7 | 1.0ab | | | | |
| San Simon | 9.1 | 9.5 | 19.8 | 12.8b | 1.5 | 1.9 | 1.7 | 1.7a | 1.0 | 0.7 | 0.8 | 0.8b | | | | |
| Tucson | 7.7 | 8.2 | 8.4 | 8.1b | 1.1 | 1.0 | 0.9 | 1.0a | 2.1 | 0.5 | 1.9 | 1.5a | | | | |
| Barstow | 22.5 | 13.8 | 22.8 | 19.7a | 0.9 | 0.8 | 1.2 | 1.0a | 2.2 | 2.2 | 1.1 | 1.8a | | | | |
| $\overline{X}$ | 13.6a | 9.5a | 15.2a | | 1.5a | 1.5a | 1.6a | | 1.7a | 1.2a | 1.2a | | | | | |

† Sampling positions: C = canopy center; E = canopy edge; B = between canopies. $\overline{X}$ = mean.
‡ Means within columns for each property followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.
§ Means within rows for each property followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.

**Table 6—Mean blue panicgrass heights and total plant biomass (roots plus shoots) after 42 d of growth on soils collected at five creosotebush sites.**

| Sites | C† | E | B | $\bar{X}$ |
|---|---|---|---|---|
| | Mean height, cm | | | |
| Carlsbad | 21 | 18 | 14 | 17.7b‡ |
| Las Cruces | 18 | 16 | 11 | 15.0b |
| San Simon | 12 | 11 | 7 | 10.0b |
| Tucson | 16 | 10 | 7 | 11.0b |
| Barstow | 46 | 38 | 11 | 31.7a |
| $\bar{X}$ | 22.6a§ | 18.6a | 10.0b | |
| | Mean total plant mass, g pot$^{-1}$ | | | |
| Carlsbad | 5 | 4 | 3 | 4.0b |
| Las Cruces | 5 | 4 | 2 | 3.7b |
| San Simon | 3 | 2 | 1 | 2.0c |
| Tucson | 6 | 4 | 2 | 4.0b |
| Barstow | 11 | 8 | 4 | 7.7a |
| $\bar{X}$ | 6.0a | 4.4b | 4.0b | |

† Sampling position: C = canopy center; E = canopy edge; B = between canopies. $\bar{X}$ = mean.
‡ Means within columns for each measurement followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.
§ Means within rows for each measurement followed by the same letter are not significantly different ($\alpha$ = 0.05) by Duncan's multiple range test.

curred between soil $NO_3^-$-N and total seedling biomass of Lehmann lovegrass ($r$ = 0.64; NS) but correlations were not significant.

## IMPLICATIONS

Arid rangelands infested with creosotebush have been plowed and seeded for 90 yr (4). Tillage reduces creosotebush competition and prepares a seedbed. However, deep plowing to 30 cm dilutes $NO_3^-$-N near the soil surface, and may have inadvertently reduced the probability of establishing perennial grasses. If $NO_3^-$-N concentrations under creosotebush canopies are adequate for seedling growth, and concentrations between canopies are inadequate, then soil mixing could result in a seedbed where the average $NO_3^-$-N concentration is less than ideal for initial seedling growth.

A less destructive approach would be to reduce creosotebush competition with a pelleted herbicide (11), wait for litter-fall, and then seed with a drill. Seedlings from seed planted in open areas between canopies would probably not survive, even in years of above-average rainfall (Tables 5 and 6). However, seedlings established under defoliated creosotebush canopies would have a high probability of survival due to: (i) natural accumulations of $NO_3^-$-N, (ii) additional $NO_3^-$-N and other nutrients released on the soil surface and in the soil profile after shrub shoots and roots decay, (iii) increased water infiltration as organic matter accumulates under the canopy and roots decompose, and (iv) reduced competition for soil moisture.

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