

**Effects of Water and Nitrogen Supplementation on Phenology, Plant Size, Tissue Nitrogen, and Seed Yield of Chihuahuan Desert Annual Plants**

Walter G. Whitford; Julio R. Gutierrez

*The Southwestern Naturalist*, Vol. 34, No. 4. (Dec., 1989), pp. 546-549.

---

---

- HUEY, R. B., AND E. R. PIANKA. 1981. Ecological consequences of foraging mode. *Ecology*, 62:991-999.
- LEWIS, T. H., AND M. J. JOHNSON. 1856. Notes on a herpetological collection from Sinaloa, Mexico. *Herpetologica*, 12:277-280.
- MAGNUSSON, W. E., ET AL. 1985. The correlates of foraging mode in a community of Brazilian lizards. *Herpetologica*, 41:324-332.
- McGOVERN, G. M., J. C. MITCHELL, AND C. B. KNISLEY. 1984. Field experiments on prey selection by the whiptail lizard, *Cnemidophorus inornatus*, in Arizona. *J. Herpetol.*, 18:347-349.
- MITCHELL, J. C. 1979. Ecology of southeastern Arizona whiptail lizards (*Cnemidophorus*: Teiidae): population densities, resource partitioning, and niche overlap. *Canadian J. Zool.*, 57:1487-1499.
- PIANKA, E. R., AND W. S. PARKER. 1975. Ecology of horned lizards: a review with special reference to *Phrynosoma platyrhinos*. *Copeia*, 1975:141-162.
- POWELL, G. L., AND A. P. RUSSELL. 1984. The diet of the eastern short-horned lizard (*Phrynosoma douglassi brevirostre*) in Alberta and its relationship to sexual size dimorphism. *Canadian J. Zool.*, 62:428-440.
- SCHOENER, T. W. 1967. The ecological significance of sexual dimorphism in size in the lizard *Anolis conspersus*. *Science* 155:474-477.
- . 1968. The *Anolis* lizards of Bimini: resource partitioning in a complex fauna. *Ecology*, 49:704-726.
- SCHOENER, T. W., J. B. SLADE, AND C. H. STINSON. 1982. Diet and sexual dimorphism in the very catholic lizard genus, *Liocephalus* of the Bahamas. *Oecologia*, 53:160-169.
- SIMON, C. A. 1976. Size selection of prey by the lizard, *Sceloporus jarrovi*. *Amer. Midland Nat.*, 96:236-241.
- SMITH, H. M. 1939. The Mexican and Central American lizards of the genus *Sceloporus*. *Zool Ser., Field Mus. Nat. Hist.* 26:1-397.
- SPSS, INC. 1986. SPSS® users guide. Second ed. McGraw-Hill Book Company, New York, 276 pp.
- VITT, L. J., R. C. VAN LOBEN SELS, AND R. D. OHMART. 1981. Ecological relationships among arboreal desert lizards. *Ecology*, 62:398-410.
- ZAR, G. H. 1974. *Biostatistical analysis*. Prentice-Hall, Englewood Cliffs, New Jersey, 718 pp.

GARNETT R. BROOKS AND JOSEPH C. MITCHELL, (GRB) *Dept. of Biol., College of William and Mary, Williamsburg, VA 23185*, (JCM) *Dept. of Biol., Univ. of Richmond, Richmond, VA 23173*.

## EFFECTS OF WATER AND NITROGEN SUPPLEMENTATION ON PHENOLOGY, PLANT SIZE, TISSUE NITROGEN, AND SEED YIELD OF CHIHUAHUAN DESERT ANNUAL PLANTS

Two factors that have been shown to affect composition and productivity of annual plant assemblages of the Chihuahuan Desert are water and nitrogen availability (Gutierrez and Whitford, 1987; Gutierrez et al., 1988; Ludwig et al., 1989). Application of nitrogen fertilizer increased biomass production of annual plants in the northern Mojave Desert (Romney et al., 1978; Williams and Bell, 1981). Williams and Bell (1981) found that tissue nitrogen concentrations were lowest in the vegetative parts of nitrogen-responsive species and that fertilizer application elevated nitrogen concentrations of reproductive structures, leaves, and roots in nitrogen-deficient plants.

Previous studies on responses of annual plants of the Chihuahuan Desert to irrigation and nitrogen fertilization focused on population densities, community composition, and biomass production (Gutierrez and Whitford, 1987; Gutierrez et al., 1988; Ludwig et al., 1989). In studies in the Chihuahuan Desert, *Astragalus nuttallianus* and *Eriastrum diffusum* produced higher biomass on watered plots but were absent or produced low biomass on nitrogen-fertilized plots (Gutierrez and Whitford, 1987; Gutierrez et al., 1988). Annual plants with the greatest biomass per plant and highest biomass on nitrogen-fertilized plots were *Lepidium lasiocarpum* and *Chaenactis stevioides* (Gutierrez and Whitford, 1987; Gutierrez et al., 1988). We measured nitrogen content of plant parts, seed yield, and plant mass of

TABLE 1—Date of flowering of four species of Chihuahuan Desert annuals subjected to irrigation of 0 mm, 6 mm, 24 mm of water/month with (+N) and without nitrogen fertilization.

Species	0 mm	0 mm + N	6 mm	6 mm + N	24 mm	24 mm + N
<i>Astragalus nuttallianus</i>	25 May	10 May	20 April	20 April	20 April	31 March
<i>Chaenactis stevioides</i>	10 May	20 April	10 May	10 May	10 May	10 May
<i>Eriastrum diffusum</i>	10 May	10 April	10 May	10 May	10 May	10 May
<i>Lepidium lasiocarpum</i> <sup>1</sup>	10 May	20 April		10 May	20 April	15 May

<sup>1</sup> Did not flower in sampling quadrats subjected to irrigation of 6 mm of water/month without weekly nitrogen fertilization.

four species of spring annual plants grown under different water and soil nitrogen conditions. We hypothesized that nitrogen would have little effect or a detrimental effect on the nitrogen-fixing legume *A. nuttallianus*. We hypothesized that water would have the greatest effect on the species of annuals that exhibit little or no growth response to soil nitrogen availability (*E. diffusum* and *E. nuttallianus*). Plant tissue nitrogen and seed production were hypothesized to increase in the nitrogen fertilizer-responsive species, *L. lasiocarpum* and *C. stevioides*.

Density, biomass and fruit production, and tissue nitrogen content were measured on four species of annual plants harvested from experimental plots subjected to irrigation and nitrogen fertilization. Plots were located on the Jornada Long Term Ecological Research Site, 40 km NNE Las Cruces, New Mexico in an area dominated by creosotebush, *Larrea tridentata* (Gutierrez et al., 1988). We used three replicate plots, 7 by 15 m, for each treatment: no water added; water added at 6 mm/week; water added at 25 mm/month in a single irrigation. Each plot was split, and 10 g/m<sup>2</sup> of NH<sub>4</sub>NO<sub>3</sub> fertilizer were added to the downslope half of each plot in January. Density and biomass of the four numerically dominant spring annuals were estimated by sampling five 0.16-km<sup>2</sup> quadrats in each treatment at peak biomass. In April, three complete plants of each species were harvested from each plot and separated into leaves, fruits, stem, and roots, dried for chemical analysis, and ground in a Wiley Mill. These ground plant parts were subjected to micro Kjeldahl digest in a block digester. Nitrogen content of the digest was measured using the colorimetric method (Fisher et al., 1987) by a Scientific Instruments autoanalyzer.

The absence of a pattern in the flowering phenologies of the spring annuals examined in this study is evidence that each species responds differently to the availability of or the resource ratio of water and nitrogen. High nitrogen accelerated flowering in *A. nuttallianus* except when combined with frequent water addition (Table 1). Supplemental water and nitrogen had no effect on the flowering phenology of *E. diffusum*. The flowering phenology of *C. stevioides* was affected only by the no-water, nitrogen treatment. The effects of water and nitrogen on the flowering of *L. lasiocarpum* were variable (Table 1).

Added water resulted in greater average plant size in *A. nuttallianus*; added nitrogen produced larger plants in the other three species especially on the watered plots (Table 2). There was a significant water-nitrogen interaction in *E. diffusum* and *L. lasiocarpum*. These data are consistent with the observations of Ludwig et al. (1989) that increases in production of desert annuals with nitrogen fertilization are a result of increased plant size of nitrogen-responsive species and not the result of increases in density.

Tissue nitrogen levels ranged between 0.005% in the roots of *E. diffusum* growing in the unwatered, unfertilized plots to 2.24% in fruits of *L. lasiocarpum* growing in the 6 mm/week, nitrogen-fertilized plots (Table 2). Nitrogen contents of annual plant tissues were <1% except for *L. lasiocarpum* in the watered, fertilized plots. *Astragalus nuttallianus* exhibited increased tissue nitrogen and higher seed yield with added water but no difference attributable to added nitrogen (Table 2). Added nitrogen had a marked effect on seed yield in *C. stevioides* and *L. lasiocarpum*; both species had higher biomass and seed yield in the nitrogen-fertilized plots. Water supplementation elevated tissue nitrogen levels in *A. nuttallianus* by 10 to 15 times, but, in *E. diffusum*, only by two to three times. *Astragalus nuttallianus* has well-developed nodules on its roots (pers. obser.) presumably containing nitrogen-fixing *Rhizobium* sp.; hence, irrigation would have eliminated water limitation for the plant and its symbionts. *Eriastrum diffusum* achieves numerical and biomass dominance in assemblages on nitrogen-poor, relatively dry soils (Gutierrez and Whitford, 1987). However, mean plant size was greater in the 6 mm/week plus

TABLE 2—Tissue nitrogen, mean numbers of seeds and mean mass per plant of four species of spring annual plants from the Chihuahuan Desert on plots receiving supplemental water (6 and 25 mm) and nitrogen (+N) fertilization compared to plants from unwatered (0 mm), unfertilized plots.

Species	Treatment						Significant differences among treatments
	0 mm	0 mm + N	6 mm	6 mm + N	25 mm	25 mm + N	
<i>Astragalus nuttalianus</i>							
Leaves	0.080	0.080	0.350	0.430	0.320	0.350	W
Stems	0.010	0.050	0.220	0.190	0.150	0.220	W
Fruits	0.020	0.040	0.310	0.410	0.470	0.340	W
Roots	0.020	0.010	0.060	0.050	0.040	0.060	W
$\bar{X}$ no. of seeds	5	12	90	119	137	98	W
$\bar{X}$ mass/plant (g)	0.040	0.110	2.290	1.000	1.080	1.220	
<i>Chaenactis stevioides</i>							
Leaves	0.040	0.070	0.040	0.080	0.030	0.140	N
Stems	0.070	0.160	0.110	0.210	0.110	0.440	N
Fruits	0.120	0.180	0.160	0.280	0.180	0.490	N
Roots	0.020	0.030	0.020	0.030	0.020	0.060	N
$\bar{X}$ no. of seeds	1,839	2,828	2,463	4,323	2,824	7,699	N
$\bar{X}$ mass/plant (g)	5.400	16.000	3.700	25.800	11.600	30.200	N
<i>Eriastrum diffusum</i>							
Leaves	0.070	0.100	0.130	0.150	0.160	0.290	W
Stems	0.010	0.020	0.020	0.060	0.050	0.090	W
Roots	0.006	0.005	0.010	0.010	0.010	0.020	W
$\bar{X}$ mass/plant (g)	0.200	0.300	0.300	1.600	0.800	1.300	N, W × N
<i>Lepidium lasiocarpum</i>							
Leaves	0.010	0.020	0.000	0.040	0.007	0.030	
Stems	0.060	0.290	0.230	0.890	0.070	0.700	N
Fruits	0.240	0.980	0.360	2.240	0.240	1.760	N
Roots	0.010	0.030	0.020	0.060	0.010	0.080	W, N, W × N
$\bar{X}$ no. of seeds	1,071	4,306	1,585	9,873	1,069	7,755	N
$\bar{X}$ mass/plant (g)	1.100	3.700	0.900	7.200	0.700	8.900	N, W × N

<sup>1</sup> Two-way analysis of variance test of water (W) treatments (0, 6, and 25 mm), nitrogen (N) treatments (with and without nitrogen fertilization), and their interaction (W × N).

nitrogen fertilizer (Table 2) than in the 6 mm/week without fertilizer. This may have resulted from leaching of nitrate by frequent wetting.

Williams and Bell (1981) reported root and shoot nitrogen concentrations of roots and shoots of 10 species of annuals. The lowest soil nitrogen they reported was 0.09%, which is higher than the root nitrogen of any of the species we measured. Similarly, most of the stem and fruit nitrogen levels measured in our study were lower than those reported by Williams and Bell (1981). These differences may be the result of differences in analytical technique or may reflect species differences.

As Williams and Bell (1981) suggest, it is important to distinguish between nitrogen-responsive annual plant species and those which are only water-responsive. Nitrogen-responsive species will tend to dominate nitrogen-rich microsites, and the size and tissue nitrogen content of individual plants of these species will reflect the nitrogen availability of the microsite. Those species not responsive to nitrogen availability may exhibit increased plant size on slightly nitrogen-enriched microsites and may increase tissue nitrogen on sites with favorable water supply. Thus, the quality of annual plants as a food source for animals and the production of seed varies directly with available soil nitrogen. These data provide additional evidence which demonstrates that we must consider water and nitrogen avail-

ability as primary determinants of spatial and temporal heterogeneity and the biology of the component species if we are to understand the production, composition, and distribution of annual plant assemblages.

This study was supported by grant no. BSR 8612106 from the National Science Foundation and is a contribution of the Jornada Long Term Ecological Research Program.

#### LITERATURE CITED

- FISHER, F. M., L. W. PARKER, J. ANDERSON, AND W. G. WHITFORD. 1987. Nitrogen mineralization in a desert soil: interacting effects of soil moisture and nitrogen fertilizer. *Soil Sci. Soc. Amer. J.*, 51:1033-1040.
- GUTIERREZ, J. R., AND W. G. WHITFORD. 1987. Chihuahuan Desert annuals: importance of water and nitrogen. *Ecology*, 68:2032-2045.
- GUTIERREZ, J. R., O. A. DASILVA, M. I. PAGANI, D. WEEMS, AND G. WHITFORD. 1988. Effects of different patterns of supplemental water and nitrogen fertilization on productivity and composition of Chihuahuan Desert annual plants. *Amer. Midland Nat.*, 119:336-343.
- LUDWIG, J. A., W. G. WHITFORD, AND J. M. CORNELIUS. 1989. Effects of water, nitrogen and sulfur amendments on cover, density and size of Chihuahuan Desert ephemerals. *J. Arid. Environ.*, 16:35-42.
- ROMNEY, E. M., A. WALLACE, AND R. B. HUNTER. 1978. Plant response to nitrogen fertilization in the northern Mojave Desert and its relationship to water manipulation. Pp. 232-243, in *Nitrogen in desert ecosystems* (N. E. West and J. Skujins, eds.). Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, 354 pp.
- WILLIAMS, R. B., AND K. L. BELL. 1981. Nitrogen allocation in Mojave Desert winter annuals. *Oecologia*, 48:145-150.

WALTER G. WHITFORD AND JULIO R. GUTIERREZ, *Dept. of Biol., New Mexico State Univ., Las Cruces, NM 88003* (Present address of JRG: *Departamento de Biología, Universidad de La Serena, Chile*).

#### EFFECT OF ELIMINATING SUBTERRANEAN TERMITES ON THE GROWTH OF CREOSOTE BUSH, *LARREA TRIDENTATA*

Several studies in the northern Chihuahuan Desert have shown that subterranean termites affect soil properties (Parker et al., 1982; Brown, 1983; Elkins et al., 1986). Parker et al. (1982) compared annual plants on a series of plots from which termites had been eliminated with those on plots with termites present and found that, although total annual plant diversity and biomass were not different, dominant species on termite-free plots ranked considerably lower than those on plots where termites were present. Parker et al. (1982) attributed these changes in species dominance to increased nitrogen levels in surface soils from which termites had been eliminated. In a subsequent study, Elkins et al. (1986) reported that water infiltration was significantly lower on plots where termites had been removed. Thus, plots without termites are characterized by higher soil nitrogen and lower water availability. Gutierrez and Whitford (1987) demonstrated that the productivity, life span, and species assemblages of annual plants of the Chihuahuan Desert are a function of the interaction between soil nitrogen and water availability. Shifts in annual plant productivity and species composition which resulted from termite removal resulted from increased nitrogen and decreased soil moisture on the termite-free plots.

Soils devoid of termites are more compacted (Elkins et al., 1986), and nitrogen concentrations in the soil surface decrease with depth. This should affect the growth of deep-rooted shrubs. We studied the effects of water supplementation and termite removal on shoot growth of the common Chihuahuan Desert shrub *Larrea tridentata* to test the hypothesis that reduced infiltration by removal of termites would reduce growth rates of the shrub.

The study area was located at the Jornada Long Term Ecological Research site on the New Mexico State University Experimental Ranch, 40 km NNE of Las Cruces, Dona Ana Co., New Mexico. This site was a desert watershed that emptied into an ephemeral lake. The watershed varied in elevation