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Effects of nitrogen amendment on annual plants in the Chihuahuan Desert

H.T. MUN and W.G. WHITFORD[1]
Department of Biology, Kongju National Teachers University, Kongju, Chungnam 314-701, Korea.
[1]Department of Biology, New Mexico State University, Las Cruces, NM 88003, USA

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Abstract

Effects of nitrogen amendments on spring annual plant distribution, primary production, and species diversity in a semi-arid environment were studied. The ecological responses of spring annual plant species to nitrogen differed between species, and between sites. The distribution of each species in a control transect was wider than in a nitrogen-treated transect. Annual plant species diversity at each station in the control transect was higher than that of the nitrogen-treated transect. The lower site of the Lower Basin Slope areas had the highest species diversity (0.94 for the control and 0.84 for the nitrogen-treated), and the Upper Basin Slope area, shrub vegetation zone, had the lowest species diversity (0.27 for the control and 0.05 for the nitrogen-treated) in both transects. Inorganic nitrogen in the nitrogen-treated transect soils was consistently higher than that in the control transect soils; however, the former showed more fluctuation from station to station than the latter. Above-ground biomass of spring annual plants in the nitrogen-treated transect was consistently higher than that in the control at each station. The maximum above-ground biomass in the control and nitrogen-treated transect was $24.4 \pm 4.4\,g\,m^{-2}$ and $61.2 \pm 10.6\,g\,m^{-2}$, respectively. Variations in above-ground biomass along the transect did not parallel with the variation in inorganic nitrogen in soils and species diversity.

Introduction

The effects of various exogenous factors on plant species composition and ecological processes that influence terrestrial plant communities have been investigated, including the effects of application of fertilizer on communities (Kirchner, 1977; Milton, 1940; Milton and Davies, 1947; Silvertown, 1980). Some of these studies have demonstrated that species composition may be controlled by altering the grazing and fertilizer regime.

After water, nitrogen is generally considered to be the limiting factor to plant growth in North American deserts (West and Skujins, 1978). Nitrogen fertilizer greatly increased production of annual herbs in the northern Mojave Desert (Wallace *et al.*, 1978), and increased the biomass production of the shrub, *Larrea tridentata*, the grass, *Erioneuron pulchellum*, and some herbaceous annuals in the Chihuahuan Desert (Ettershank *et al.*, 1978; Gutierrez and Whitford, 1987). Recently, Tilman (1982) proposed that the species diversity of natural plant communities should depend on the supply rates of the limiting resources (nutrients, space), with maximum diversity in moderately resource-poor habitat and with diversity decreasing in either resource-rich or resource-poor habitats. Since 1983, a large-scale experiment has been conducted at the Jornada LTER site in the Chihuahuan Desert (New Mexico, USA), examining amendment effects of a limiting resource (nitrogen) across a desert landscape. Cornelius and Cunningham (1987) reported increased cover of annual plants and decreased species diversity with nitrogen amendments. Because the effects of increased nitrogen on ecological processes should vary between different species, the effects of nitrogen amendment on the total annual plant assemblages should vary along the transect.

This study was to examine the effects of chronic nitrogen amendment on annual plant species distribution, biomass production, and diversity patterns along the transects in the Chihuahuan Desert.

Study area and methods

Study area

The study was conducted on the Jornada Long Term Ecological Research site, about 40 km north of Las Cruces, New Mexico. The long-term precipitation is 225 mm/yr, mostly as summer convectional rainfall. Two parallel 2.7 km transects (70 m apart) were established in 1981. Each transect ranged from a piedmont area (elevation *ca.* 1400 m) to a small playa basin (elevation *ca.* 1300 m). Several major vegetation zones, based on the cover of perennial species, have been identified along the transects (Table 1, Wierenga *et al.*, 1987). Each transect has a numbered stake at every 30 m intervals. A 30 m wide strip centered on one transect was amended with nitrogen fertilizer ($30\,g\,NH_4NO_3\,m^{-2}$) in August 1983 and 1984, March 1985, August 1985, July 1986 and September 1987.

Methods

Spring annual plants were harvested from the control and nitrogen-treated transects at maximum above-ground biomass in April 1988 within $1\,m^2$ quadrats. The plants were sorted by species, dried, and weighed after counting individual numbers of each species. We sampled four quadrats at each 30 m interval, and combined five adjacent intervals into one station to determine frequency, density, above-ground biomass, and species diversity. Vegetation zones corresponding to stations are shown in Table 1. Plant species diversity was calculated using the Shannon-Wiener index based on abundance (H′) and above-ground biomass ($H'_{biomass}$) from the following formulation

$$H' = -\sum_{i=1}^{S} P_i \log_{10} P_i$$

Concentration of dominance (CD) was calculated using the Simpson's index:

$$CD = \sum_{i=1}^{S} (P_i)^2$$

Where P_i is the proportion of abundance, or biomass, of the i th species in sample in each station. Evenness (J′) was calculated after Pielou (1966):

$$J' = H'/H'_{max}, (H'_{max} = \log S)$$

where S is the number of species in the sample.

Soil samples for NH_4-N and NO_3-N determination were collected nine times at every interval during three years from 1984 to 1986. 10 g of fresh soil was placed into 100 mL of 2*N* KCl, shaken thoroughly, and allowed to equilibriate for 24 h. The filtrate was analyzed for NH_4-N and NO_3-N using an automated salicylate procedure (Nelson, 1983). Soil samples for total nitrogen determination were collected four times at every interval during three years from 1984 to 1986. Soil samples were air-dried and then ground with a motorized mortar and pestle to pass a 0.15 mm sieve before micro-Kjeldahl digestion. NH_4-N in the digest was measured by using an automated salicylated procedure (Nelson, 1983).

Results

Distribution

Patterns of spring annual plant distribution, in general, were similar between the control and nitrogen-treated transects (Fig. 1). *Mentzelia albicaulis, Linanthus bigelovii* and *Gilia mexicana* were restricted to the Piedmont area. On the other hand, *Salsola kali, Chenopodium incanum* and *Erigonum trichopes* were restricted to the Basin Slope area. *Lesquerella gordonii* was confined only

Table 1. Vegetation zones and station position along the transect

Vegetation	Stations
Playa-grassland (*Panicum obtusum*)	1–2
Lower Basin Slope-grassland (*Aristida longiseta*)	3–11
Upper Basin Slope-shrubland (*Larrea tridentata*)	12–15
Lower Piedmont-grassland (*Erioneuron pulchellum*) *Bouteloua eriopoda, Eragrostis lehmanniana*)	16–17
Upper Piedmont-grassland (*Bouteloua eriopoda*)	17–18