Biol Fertil Soils (1996) 21:128–130

SHORT COMMUNICATION

Shlomo Sarig · Andreas Fliessbach · Yosef Steinberger

Microbial biomass reflects a nitrogen and phosphorous economy of halophytes grown in salty desert soil

Received: 25 April 1994

Abstract Seasonal variations in soil salinity were recorded under the canopy of two halophyte shrubs typical of the hot, dry Negev desert, *Zygophyllum dumosum* and *Reaumuria negevensis*. The effects of the fluctuating soil salinity levels on total soluble N and on microbial biomass N and P were also monitored. The microhabitat of the shrubs showed differences in trend and magnitude of soil mineral N, the $NO_3^- : NH_4^+$ ratio, and microbial N and P. The trends were assumed to be governed by the various mechanisms operating in the shrubs in order to survive salty environments. Data from the current study are discussed in terms of the assumption that the halophyte has developed ecophysiological strategies that force microbial communities coexisting in its microhabitat towards adaptation aimed at withstanding a fluctuating environment, and hence towards a beneficial plant-microorganism relationship.

Key words Microbial biomass N · Microbial biomass P · Halophytes · Desert · Salinity · *Zygophyllum dumosum* · *Reaumuria negevensis*

Introduction

A major characteristic of dry desert vegetation is the scattered distribution of perennial shrubs, which cause a horizontal differentiation of soil properties (Charley and West 1978; Hadley and Szarek 1981; Jackson and Caldwell 1993). Usually, the limited nutrient supply in desert soil is not the result of slow nutrient cycling. Actually, decomposition is surprisingly fast and is driven by an abundant soil microfauna that contributes to nutrient turnover (Schlesinger et al. 1990). However, during most of the year, the soil of the desert becomes extremely dry, leading to nutrient deficiencies, particularly of N, because of lack of mobility (Ashraf and McNeilly 1994). In addition, arid soils frequently show accumulations of calcium carbonate that buffer pH in the range of 7–8, leading to P unavailability. In the hot dry Negev desert of Israel, the physical and chemical components of different soil layers and the salinity of the underground water are the major factors that determine the nature of the vegetation (Tadmor et al. 1962; Evenari et al. 1982).

“Islands of salinity” are created as a result of the scattered occurrence of perennial halophytes and their mechanisms of salt resistance. These islands are formed because the plants absorb salts through their root system, translocate them to leaves and redeposit them on the ground (Waisel 1973). Since microbial activity, which mediates mineral biogeocycling, is of utmost importance (West and Skujins 1978; Skujins 1984), we postulate that the microbial biomass acts as an important source of available N and P in this poor and harsh environment. In the current study, different reciprocal relationships were found between the microbial biomass and the soil salinity under the two common halophyte species; *Reaumuria negevensis* and *Zygophyllum dumosum* both belong to the chloride absorbing xerohalophytes, suggesting development of microbial adaptation to specific conditions.

Materials and methods

We selected a study site in the northern highland of the Negev desert (34°46′E/30°47′N) of Israel to examine seasonal trends in N and P concentrations in the soil and in the microbial biomass. This area consists of rocky slopes with shallow, saline, gray lithogenic calcareous soils (18% clay, 20% silt, 62% sand; pH 7.9; 42% $CaCO_3$; approximately 16–20% field water-holding capacity). This desert has a Mediterranean-type climatic cycle of mild rainy winters (5–14 °C in January) and hot dry summers (18–23 °C in June). The annual rainfall averages 90 mm, with additional moisture in the form of approximately 35 mm dew. The annual potential evaporative demand approximates 2600 mm. The perennial vegetation is dominated by

---

S. Sarig (✉) · A. Fliessbach[1] · Y. Steinberger
Department of Life Sciences, Bar-Ilan University,
Ramat Gan, 52900, Israel

Present address:
[1] Institut für Bodenbiologie, FAL, Braunschweig, Bundesallee 50, Germany

a desert dwarf-shrub association, in which the most common species are two xerohalophytes, *Zygophyllum dumosum* and *Reaumuria negevensis* (Evenari et al. 1982).

Soil samples were collected monthly during winter and spring (November–April) and bimonthly during summer (May–September), from the upper soil layer (0–10 cm) under the canopy of eight individual plants of each of the two shrub species. For each species, the eight individual plants were divided into four pairs (based on location and similarity in morphological dimensions) in which soil samples were pooled, thus giving four replicates per species. Soil moisture was measured gravimetrically and expressed as percent water-holding capacity. Salinity was measured in 1 : 2 soil extracts and expressed as electrical conductivity. Total soluble N ($NH_4^+ + NO_3^-$) and phosphate were determined automatically (Boltz and Mellon 1948; Kroon 1993) with a Skalar autoanalyzer. Microbial biomass N and P and were determined using fumigation-extraction methods (Brookes et al. 1982, 1985).

Results and discussion

During the study period a total of 162 mm of rainfall occurred (80% more than the multiannual average), which was reflected in the soil moisture behavior (approximately 60% water-holding capacity during December–February and 10–20% throughout the rest of the year). Soil salinity (Table 1) varied considerably within the annual cycle and significant differences in soil salinity were observed between seasons and between shrubs. The electrical conductivity of soil under the canopy of *Z. dumosum* reached its highest level during the winter season, while that under *R. negevensis* showed two peaks, one during the rainy season and a second in mid-summer. Preliminary research showed that no marked upward movement of salts takes place during the dry summer in this coarse-sandy soil. It is evident that salinity fluctuation is predominantly governed by salt-excluding mechanisms in the two halophytes. *R. negevensis* directly excretes a large amount of salts via external glands on the leaf surface. Therefore the salt may frequently be washed out into the soil by rain, dew, and even by wind. *Z. dumosum,* upon dehydration during the late summer, sheds its leaflets, which apparently contain most of the salts (Tadmor et al. 1962; Reimold and Queen 1974).

The two shrub species exhibited different seasonal patterns in soil mineral N (Table 2). Our study on this nutrient-poor ecosystem revealed a reciprocal relationship between this N pool and the active growth periods of the two shrubs. N levels in the microbial biomass (Table 3) and in the soil were inversely correlated, indicating that the microbial biomass serves as an immediate and highly turned over source of available nitrogen corresponding to period of intense plant growth.

Changes in the $NO_3^- : NH_4^+$ ratio (Table 2) can be viewed from an ecophysiological standpoint of the plant-microorganism association. Since the roots of *Z. dumosum* are fast-growing and respond rapidly (within a few hours) to water availability, commencing in early winter (December) (Kinsbursky et al. 1990), the high $NO_3^- : NH_4^+$ ratio at this time represents a preferable form of N for plant uptake. In *R. negevensis*, the high ratio occurs in spring and corresponds to the onset of active plant growth. In this case, low levels of NO_3 in winter may be due to increased sensitivity of nitrifying bacteria to more salty soil (McKormic and Wolf 1980) and since the plant is metabolically less active, and since NO_3 is more vulnerable to leaching, the lower ratio has an environmental advantage.

Calcareous soils in the hot dry desert of the Negev are low in plant-available P (less than 1 ppm $NaHCO_3$-extractable P; Evenari et al. 1982). Hence, the fairly high amounts of P in the microbial biomass (Table 3) suggest that the microbial pool is the main source of plant-available P.

Soil salinity and microbial biomass N and P were negatively correlated (Fig. 1). However, the correlation lines exhibited different slopes for the two shrubs. Frequent changes in soil salinity during the year under *R. negevensis* did not significantly affect microbial biomass N and P, although extreme changes in salinity occurred. In contrast, a small increase in soil salinity under *Z. dumosum* caused a significant decrease in microbial biomass N and P.

Data from the current study indicate that different salt-resistant mechanisms in various desert halophytes can affect spatial and temporal salt concentration patterns, resulting in changes in microbial biomass and activ-

Table 1 Soil salinity under the canopy of two shrubs as measured by electrical conductivity (dS m^{-1}). Values are means ± SE

	December (Early winter)	March (Spring)	July (Mid-summer)
Reaumuria negevensis	11.8 ± 1.1	1.6 ± 0.2	4.2 ± 0.3
Zygophyllum dumosum	3.7 ± 0.3	0.9 ± 0.1	1.2 ± 0.1

Table 2 Mineral N (and $NO_3^- : NH_4^+$ ratio) in soil under the canopy of two shrubs (mg N kg^{-1}). For further explanations see Table 1

	December	March	July
Reaumuria negevensis	16 ± 2 (0.6)	8 ± 2 (2.5)	21 ± 3 (0.7)
Zygophyllum dumosum	32 ± 5 (2.7)	22 ± 3 (1.2)	17 ± 2 (0.4)

Table 3 Microbial biomass N and P in soil under the canopy of two shrubs (mg kg^{-1}). For further explanations see Table 1

		December	March	July
Reaumuria negevensis	N	27 ± 1.0	54 ± 3.3	38 ± 2.7
	P	11 ± 0.8	13 ± 1.1	12 ± 1.0
Zygophyllum dumosum	N	24 ± 1.7	44 ± 2.2	85 ± 5.9
	P	10 ± 1.1	12 ± 1.0	22 ± 1.9

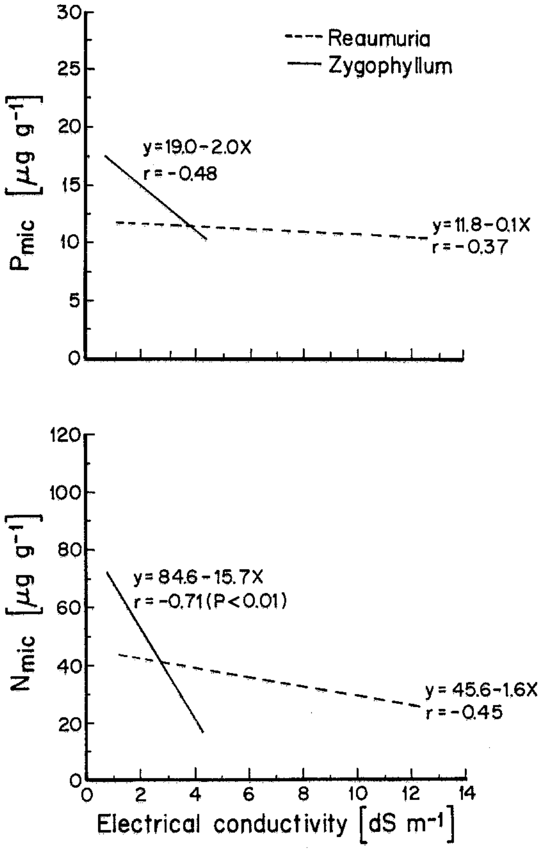

Fig. 1 Relationship between soil salinity and microbial biomass N (N_{mic}) and P (P_{mic}) under two shrubs, *Reaumuria negevensis* and *Zygophyllum dumosum*

ity. Microbial adaptation to the fluctuating environment may serve as a valuable mediator of plant-available nutrients, by immobilizing N and P.

These relationships may represent an evolutionary process, aiding in the conservation of essential nutrients in a poor desert ecosystem.

References

Ashraf M, McNeilly T (1994) Response of three arid zone grasses to N deficiency: A greenhouse study. Arid Soil Res Rehab 8:125–136

Boltz DF, Mellon MG (1948) Spectrophotometric determination of phosphate as molydiphosphoric acid. Anal Chem 20:749–751

Brookes PC, Powlsen DS, Jenkinson DS (1982) Measurement of microbial biomass phosphorus in soil. Soil Biol Biochem 14:319–329

Brookes PC, Landman A, Pruden G, Jenkinson DS (1985) Chloroform fumigation and the release of soil nitrogen: A rapid direct extraction method to measure microbial biomass nitrogen in soil. Soil Biol Biochem 17:837–842

Charley JL, West NE (1978) Micropatterns of nitrogen mineralization activity in soils of some shrub-dominated semi-desert ecosystem in Utah. Soil Biol Biochem 9:357–365

Evenari M, Shanan L, Tadmor N (1982) The Negev: The challenge of a desert. Harvard University Press, Cambridge

Hadley NF, Szarek SR (1981) Productivity of desert ecosystems. Bioscience 31:747–752

Jackson RB, Caldwell MM (1993) The scale of nutrient heterogeneity around individual plants and its quantification with geostatistics. Ecology 74:612–614

Kinsbursky RS, Degani R, Barnes G, Steinberger Y (1990) Root-microbial population dynamics in a soil profile under the canopy of the desert shrub *Zygophyllum dumosum*. J Arid Environ 19:261–267

Kroon H (1993) Determination of nitrogen in water: Comparison of a continuous-flow method with on-line UV digestion with the original Kjeldal method. Anal Chim Acta 276:287–293

McCormic RW, Wolf DC (1980) Effect of sodium chloride on CO_2 evolution ammonification and nitrification in a Sassafras sandy loam. Soil Biol Biochem 12:153–157

Reimold RJ, Queen WH (1974) Ecology of halophytes. Academic Press, New York

Schlesinger WH, Reynolds JF, Cunningham GL, Huenneke LF, Jarrel WM, Virginia RA, Whitford WG (1990) Biological feedbacks in global desertification. Science 247:1043–1048

Skujins J (1984) Microbial ecology of desert soils. Adv Microb Ecol 7:49–92

Tadmor N, Orshan G, Rawitz E (1962) Habitat analysis in the Negev Desert of Israel. Res Counc Israel, Bull D, Botany 11:148–173

Waisel Y (1973) Biology of halophytes. Academic Press, New York

West NE, Skujins J (1978) Nitrogen in desert ecosystems. US/IBP no. 9. Dowden, Hutchinson and Ross, Stroudsburg, Pa