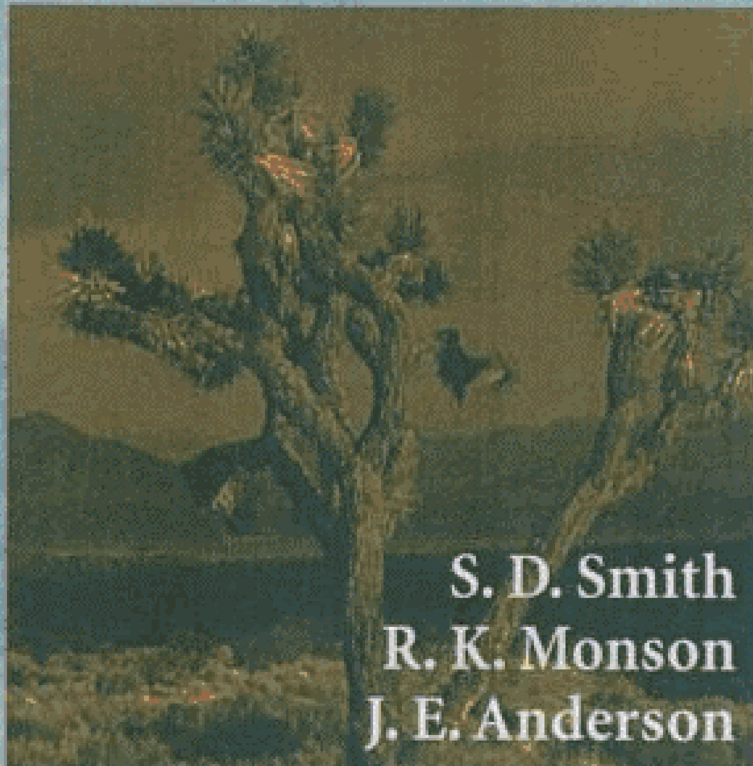
Adaptations of Desert Organisms



S. D. Smith
R. K. Monson
J. E. Anderson

Physiological Ecology of North American Desert Plants

Springer

Prof. Dr. STANLEY D. SMITH
Department of Biological Sciences
University of Nevada
4505 Maryland Parkway
Box 454004
Las Vegas, NV 89154-4004, USA

Prof. Dr. RUSSELL K. MONSON
Department of Environmental, Population
and Organismic Biology, Ramaley Building N122
University of Colorado, Campus Box 334
Boulder, CO 80309-0334, USA

Prof. Dr. JAY E. ANDERSON
Department of Biological Sciences
College of Arts and Sciences
Idaho State University
Campus Box 8007
Building 65, Memorial Drive
Pocatello, ID 83209-8007, USA

Front cover illustration: *Yucca brevifolia* (Joshua tree). Photograph taken by S.D. Smith

ISBN 3-540-53113-0 Springer-Verlag Berlin Heidelberg New York

Library of Congress Cataloging-in-Publication Data. Smith, Stanley D., 1951– Physiological ecology of North American desert plants/Stanley D. Smith, Russell K. Monson, Jay E. Anderson. p. cm. – (Adaptations of desert organisms) Includes bibliographical references (p.) and index. ISBN 3-540-53113-0 (hardcover) 1. Desert plants – Ecophysiology – West (U.S.) 2. Desert plants – Ecophysiology – Mexico. 3. Desert plants – Adaptation – West (U.S.) 4. Desert plants – Adaptation – Mexico. I. Monson, Russell K., 1954– , II. Anderson, Jay Ennis, 1937– . III. Title. IV. Series. QK133.S58 1997 581.5'2652'0979 – dc20 97-27909

Cover design: Design & Production GmbH, Heidelberg

Typesetting: Thomson Press (India) Ltd., Madras

SPIN: 10023822 31/3137/SPS – 5 4 3 2 1 0 – Printed on acid-free paper

also stimulates a self-promoting fire cycle in a community-type that had limited historical exposure to fire (Busch and Smith 1993; see Sect 10.3).

1.4 Structure and Function of North American Desert Ecosystems

1.4.1 Primary Production

Desert ecosystems exhibit low annual net primary production (ANPP) and standing biomass. Estimates of ANPP in deserts vary somewhat: Lieth (1973) proposed a range of 10 to 250 g m^{-2} $year^{-1}$ for desert scrub and 0–10 g m^{-2} $year^{-1}$ for extreme desert, and Noy-Meir (1973) proposed a range of 30 to 300 g m^{-2} $year^{-1}$ for desert ecosystems. This compares with ANPP values of 200–1500 and 600–1500 g m^{-2} $year^{-1}$ for temperate grassland and forest, respectively (Lieth 1973). This low annual primary production of desert ecosystems has been attributed to: (1) low annual rainfall; (2) low nutrient content in the soil; and (3) low production potential of desert plants (Hadley and Szarek 1981). These are not mutually exclusive factors, but since aridity is the primary climatic attribute of desert regions, it has long been assumed that low primary production in deserts is due to a lack of rainfall. This is illustrated by the fact that deserts can exhibit high productivity in wet years and that microhabitats that accumulate run-on water (e.g., large washes, playa fringes) have high productivity on a mean annual basis (Ludwig 1987).

Net primary production in terrestrial ecosystems is strongly correlated with mean annual water availability (Webb et al. 1978) and foliar standing crop (Webb et al. 1983). Primary production data from the four North American deserts (Le Houérou 1984) indicate that annual primary production correlates moderately well with annual precipitation (Fig. 7), with the arid Mojave Desert having the lowest average ANPP (25 g m^{-2} $year^{-1}$) and the semiarid Chihuahuan Desert having the highest ANPP (119 g m^{-2} $year^{-1}$). The ANPP value cited by Le Houérou (1984) for the Sonoran Desert (mean of 52 g m^{-2} $year^{-1}$), which was lower than in the drier Great Basin Desert (mean of 92 g m^{-2} $year^{-1}$), appears to be anomalously low; Whittaker and Niering (1975) quantified a mean ANPP of 109 g m^{-2} $year^{-1}$ for three Sonoran Desert scrub communities. Given this more realistic estimate, only the Mojave Desert approaches the upper ANPP boundary of 10 g m^{-2} $year^{-1}$ for extreme deserts. Le Houérou (1984) developed a parameter called "rain-use efficiency" (RUE, the quotient of annual primary production and annual precipitation; g dry wt m^{-2} $year^{-1}$ mm^{-1}). Mean RUE of the four deserts was 0.197 for the Mojave Desert, 0.19 for the Sonoran Desert (or ca. 0.4 if using the Whittaker–Niering ANPP estimate), 0.41 for the Great Basin, and 0.43 for the Chihuahuan Desert.

Correlations of annual production with rainfall are more accurate when conducted on a single site rather than across deserts and physiognomic types of

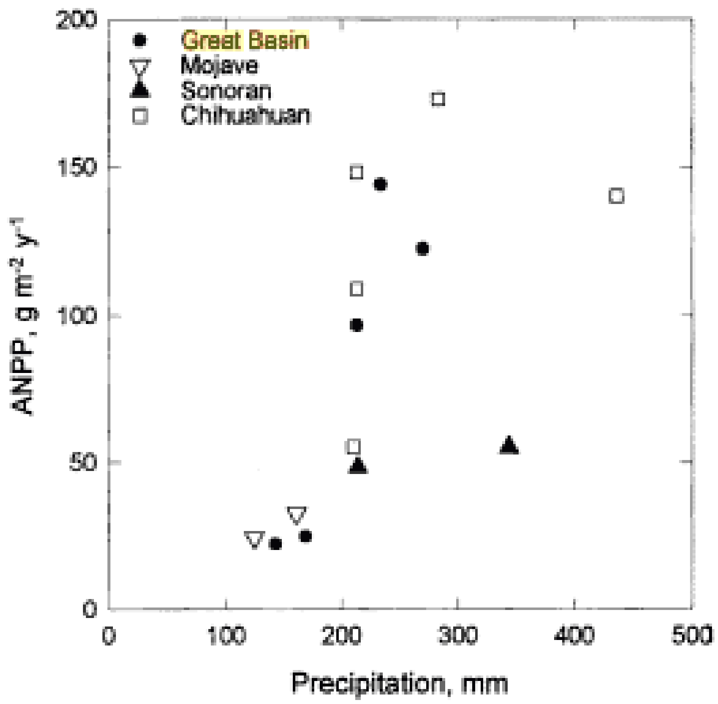


Fig. 7. Mean annual net primary production (*ANPP*) as a function of mean annual precipitation for sites within the Great Basin, Mojave, Sonoran and Chihauhuan Deserts. (Redrawn from Le Houérou 1984)

vegetation. An analysis of nine consecutive years of primary production data from Rock Valley in the Mojave Desert (Lane et al. 1984) showed that ANPP was moderately well correlated with annual precipitation (r^2=0.51), but exhibited a better correlation with annual transpiration (r^2=0.84); from an efficiency perspective, vegetation RUE showed no relationship with precipitation, whereas plant WUE was only moderately correlated with transpiration (Fig. 8). The higher correlation of ANPP with plant transpiration is not surprising, since transpiration is a direct measure of gas exchange activity in vegetation, whereas precipitation can be lost via runoff, soil evaporation, and deep drainage. Regressions of ANPP with seasonal (January–May) precipitation (r^2=0.74) and transpiration (r^2=0.90) gave even better predictive estimates. For plants that commence growth in late autumn and continue through the winter and spring, calendar-year rainfall may have little relevance to their phenological schedules and resulting productivity (Turner and Randall 1989). With the possible exception of the Chihuahuan Desert, winter rainfall has a greater effect on primary production, compared to summer rainfall. This is because winter rainfall originates from frontal systems and tends to uniformly wet the soil to deeper depths. Concurrently, lower evaporative conditions result in a greater percentage of AET occurring as transpiration. In the summer, rainfall events percolate to shallower depths (Cable 1980) and are quickly lost through evaporation from the soil. As a result, some desert shrubs do not utilize summer rains (Ehleringer et al. 1991) and do not exhibit a summer growth phase, even when presented