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PREFACE

Vadose zone dynamics and the legacy of Wilford R. Gardner

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This special issue of *Transport in Porous Media* features a multifaceted sampling of insights into "Vadose Zone Dynamics" with examples of classical problems, like those associated with evaporation and water uptake by plants, as well as more unique topics, like non-continuum descriptions of soil–air–water systems. The broad range of topics presented here are exemplary of the legacy of W. R. Gardner's contributions to the field of vadose zone hydrology. As such, we are dedicating this special issue to Dr. Wilford R. Gardner in acknowledgement of his indelible imprint on this topic and soil and water science in general, as well as in honor of his 80th birthday.

1 Brief biographical sketch

A Utah native, born in Logan in 1925, Wilford Robert Gardner enlisted in the US Army and, after a short period in the ROTC program at Stanford University, served in World War II from 1944 to 1946, earning the Bronze Star. After the war, he returned to Utah to study physics and mathematics at Utah State University (then Utah State Agricultural College) and received his BS in 1949. About a month after his graduation, he married Marjorie Louise Cole and eventually the couple had three children. He earned graduate degrees from Iowa State University in soil physics and physics in 1951 and 1953, respectively.

Wilford's post-graduate career, which spanned over half a century and included pioneering work in soil physics, water movement in soil, and sustainable management of soil and water resources, began with 13 years as a physicist at the U.S. Salinity

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Laboratory in Riverside, California. He spent 1959–1960 at Cambridge University, England and Wageningen Agricultural University, The Netherlands as part of an NSF Senior Fellowship. From 1966 to 1980 Gardner was a soil physics professor at the University of Wisconsin at Madison and in 1971–1972 was a Fulbright Fellow at the University of Ghent, Belgium. Wilford brought to Madison a wide range of experience and a sound knowledge of the origin of ideas in soil physics, especially through his lengthy and close association with Dr. Lorenzo Richards. At Madison, he fruitfully interacted with the micrometeorologist and soil microbiologist, resulting in unique contributions to soil–plant–atmosphere and soil–biota systems. Ahead of most others, the program Gardner developed was strongly field oriented, with theoretical analysis and laboratory experiments mostly serving to clarify processes in the field (see Gardner 1972).

Wilford moved to administrative positions in 1980, first as head of the Department of Soil and Water Science at the University of Arizona from 1980 to 1987 and then as dean of the College of Natural Resources at the University of California, Berkeley from 1987 to 1994. Despite his professional shift to administration, Gardner continued active involvement in research publishing ~20 journal papers during this period and investigating, for example, effects of soil spatial variability on crop responses (Warrick and Gardner 1983), temperature and solute effects on tritium diffusion in arid areas (Smiles et al. 1985), and plant-water uptake mechanisms (e.g., Gardner 1991). After receiving the honor of Dean Emeritus of the University of California at Berkeley, Wilford became an adjunct professor at Utah State in the Department of Plants, Soils, and Biometeorology in 1995.

Gardner has also made memorable impacts on soil science through his very active roles in all kinds of scientific societies, organizations, and committees, nationally as well as internationally. Examples include: National Academies of Sciences, Soil Science Society of America, American Society of Agronomy, International Soil Science Society, American Association for the Advancement of Science, Water Science and Technology Board of the National Research Council and the National Academy of Sciences. He held leadership roles on physics committees for the International Soil Science Society, the delegation to International Union of Soil Science, and he was chairman of the U.S. National Committee for Soil Science, and of the Soil Science Society of America.

2 Legacy in vadose zone dynamics

Wilford's scientific contributions are perhaps best characterized as "multifaceted", including a wide range of insights to problems in the natural environment with particular emphases on the vadose zone. With over 100 publications, many extremely highly cited, it is difficult to meaningfully summarize Gardner's impact on vadose zone science. However, we think the papers in this special issue represent a small sample of his ongoing legacy. A central and important emphasis in Gardner's research was the classical problem of transport of water in porous media associated with the soil–plant–atmosphere continuum (e.g., Gardner 1958, 1960, 1991, Gardner and Fireman 1958, Gardner and Ehlig 1962, Ehlig and Gardner 1962, Gardner and Gardner 1969, Black et al. 1969, Kirkham et al. 1974, Dalton et al. 1975). In this special issue we have included several contributions that continue to consider this classical issue. Two papers consider mathematical descriptions of small scale evaporation or plant uptake

processes, i.e., *Capillary absorption in porous sheets and surfaces subject to evaporation* by David Lockington and others and *Uptake of water from soils by plant roots* by Peter Raats. Michael Puma and colleagues present insights into the classical evapotranspiration problem at a somewhat larger scale and considering a more complex hydrological system in their paper, *Implications of rainfall temporal resolution for soil-moisture and transpiration modeling*. Wilford also made important contributions in the area of flow of water in the vadose zone, (e.g., Gardner 1958, 1959, 1967, Hillel and Gardner 1970) including early solutions of the Richards equation, using clever approximations of the hydraulic properties. Especially noteworthy, Wilford was the first to point out that an exponential dependence of the hydraulic conductivity upon the pressure head linearizes the steady-state Richards equation (e.g., Gardner 1958, Gardner and Mayhugh 1958), leading to a flood of analytical solutions starting in the mid 1960s and continuing to this day. Additional complications with unsaturated flow conditions due to soil swelling are explored in this special issue by Wei-Cheng Lo and Natalie Kleinfelter and respective co-authors in *Low-frequency dilatational wave propagation through unsaturated porous media containing two immiscible fluids* and *Mixture theory and unsaturated flow in swelling soils*, respectively. This special issue would be incomplete without some examples that explicitly represent the forward-looking spirit of Gardner's legacy, which is perhaps best represented by his pioneering work with Don Kirkham (1952) in neutron scattering to measure soil moisture; which we believe may be the first paper on this technique that has become a standard method in soil science. Thus, to complete this special issue we have included two papers that explore phenomena beyond the traditional Darcy-continuum description of vadose zone dynamics. One is by John Selker and colleagues and the other by Dani Or and Teamrat Ghezzehei, respectively titled *The geometry of gas injection into saturated homogeneous porous media* and *Traveling liquid bridges in unsaturated fractured porous media*.

References

Black, T.A., Gardner, W.R., Thurtell, G.W.: The prediction of evaporation, drainage, and soil water storage for a bare soil. Soil Sci. Soc. Am. Proc. **33**, 655–660 (1969)

Dalton, F.N., Gardner, W.R., Raats, P.A.C.: Simultaneous uptake of water and solutes by plant roots. Agron. J. **67**, 334–339 (1975)

Ehlig, C.F., Gardner, W.R.: The movement of water to plant roots. Crops Soils **14**(9), 24–25 (1962)

Gardner, W.R.: Some steady-state solutions of the unsaturated moisture flow equation with application to evaporation from a water table. Soil Sci. **85**, 228–232 (1958)

Gardner, W.R.: Solutions of the flow equation for the drying of soils and other porous media. Soil Sci. Soc. Am. Proc. **23**, 183–187 (1959)

Gardner, W.R.: Dynamic aspects of water availability to plants. Soil Sci. **89**, 63–73 (1960)

Gardner, W.R.: Water movement in the unsaturated soil profile. Proceedings of the ICID Symposium on Soil Water, vol II. pp. 224–239, Prague (1967)

Gardner W.R.: Criteria for determining the aims and directions of research in soil physics and technology. In: Hillel, D. (ed.) Optimizing the soil physical environment toward greater crop yields, pp. 1–9. Academic Press, New York (1972)

Gardner, W.R.: Modeling water uptake by roots. Irrigation Sci. **12**, 109–114 (1991)

Gardner, W.R., Ehlig, C.F.: Impedance to water movement in soil and plant. Science **138**, 522–523 (1962)

Gardner, W.R., Fireman, M.: Laboratory studies of evaporation from soil columns in the presence of a water table. Soil Sci. **85**, 244–249 (1958)

Gardner, H.R., Gardner, W.R.: Relation of water application to evaporation and storage of water. Soil Sci. Soc. Am. Proc. **33**, 192–196 (1969)

Gardner, W.R., Kirkham, D.: Determination of soil moisture by neutron scattering. Soil Sci. **73**, 391–401 (1952)
Gardner, W.R., Mayhugh, M.S.: Solutions and tests of the diffusion equation for the movement of water in soil. Soil Sci. Soc. Am. Proc. **22**, 197–201 (1958)
Hillel, D., Gardner, W.R.: Measurement of unsaturated conductivity and diffusivity by infiltration through an impeding layer. Soil Sci. **109**, 149–153 (1970)
Kirkham, M.B., Keeney, D.R., Gardner, W.R.: Uptake of water and labeled nitrate at different depths from the root zone of potato plants grown on a sandy soil. Agro-Ecosystems **1**, 31–44 (1974)
Smiles, D.E., Barnes, C.J., Gardner, W.R.: Water relations of saturated bentonite - Some effects of temperature and solution salt concentration. Soil Sci. Soc. Am. J. **49**(1), 66–69 (1985)
Warrick, A.W., Gardner, W.R.: Crop yield as affected by spatial variations of soil and irrigation. Water Resour. Res. **19**, 181–186 (1983)