#282 p. 68
#283 p. 72

Infiltration Research Planning Workshop

Part I. State of the Art Reports

Agricultural Reviews and Manuals
Science and Education Administration
U.S. Department of Agriculture

ARM-NC-4
April 1979

INFILTRATION RESEARCH PLANNING WORKSHOP
PART I. STATE OF THE ART REPORTS

October 18-20, 1977
St. Louis, Missouri

Published by Agricultural Research (North Central Region)
Science and Education Administration, U.S. Department of Agriculture
2000 W. Pioneer Parkway
Peoria, Ill. 61615

FOREWORD

The workshop objective was to review briefly the state of the art regarding knowledge of the infiltration mechanism and to begin development of a SEA research plan to expand that knowledge. Participants were asked to prepare short state-of-the-art papers relating to various aspects of infiltration. Part I presents these papers. Part II will present results of the planning task, which is still in progress at this time.

The papers present views of the individual authors and not necessarily those of the U.S. Department of Agriculture. Each paper is brief, but they provide a comprehensive overview of infiltration knowledge today and contain lists of references for readers interested in expanding their knowledge further. Copies are available from

C. R. Amerman
USDA-SEA-AR-NCR
Watershed Research Unit
207 Business Loop East
Columbia, MO 65201

AUTHOR AFFILIATIONS

C. R. Amerman, research leader, USDA-SEA-AR, Watershed Research Unit, in cooperation with th Agricultural Experiment Station, University of Missouri, Columbia 65201

D. L. Brakensiek, research leader, USDA-SEA-AR, Northwest Watershed Research Center, in cooperation with the Agricultural Experiment Station and Cooperative Extension Service of the University of Idaho, Boise 83705

R. R. Bruce, soil scientist, USDA-SEA-AR, Southern Piedmont Conservation Research Laboratory Watkinsville, Ga. 30677, in cooperation with the College Experiment Stations, The Univers of Georgia, Athens 30602

D. L. Chery, Jr., research hydraulic engineer, USDA-SEA-AR, Southeast Watershed Research Program, in cooperation with the Agricultural Experiment Station, University of Georgia, Athens 30602

R. M. Dixon, soil scientist, USDA-SEA-AR, Southwest Rangeland Watershed Research Center, in cooperation with the Agricultural Experiment Station, Tucson, Ariz. 85705

W. R. Hamon, research leader, USDA-SEA-AR, North Appalachian Experimental Watershed, Coshoct Ohio 43812, in cooperation with the Ohio Agricultural Research and Development Center, Wooster 44691

J. R. Hoover, agricultural engineer, USDA-SEA-AR, Northeast Watershed Research Laboratory, i cooperation with the Agricultural Experiment Station and Cooperative Extension Service, Pennsylvania State University, University Park 16802

A. Klute, research leader, USDA-SEA-AR, Irrigation and Soil/Plant/Water Relations Research, in cooperation with the Cooperative Extension Service of the Colorado State University, Fort Collins 80523

D. R. Linden, soil scientist, USDA-SEA-AR, in cooperation with the Agricultural Experiment Station, University of Minnesota, St. Paul 55108

R. F. Paetzold, research soil scientist, USDA-SEA-AR, National Soil Survey Laboratory, SCS, Lincoln, Nebr. 68508

W. J. Rawls, hydrologist, USDA-SEA-AR, Hydrology Laboratory, Beltsville, Md. 20705

C. W. Richardson, agricultural engineer, USDA-SEA-AR, Grassland Soil and Water Research Laboratory, Temple, Tex. 76501, in cooperation with the Agricultural Experiment Station, Texas A&M University System, College Station 77843

M. J. M. Römkens, soil scientist, USDA-SEA-AR, Sedimentation Laboratory, in cooperation with the Mississippi Agricultural and Forestry Experiment Station, Oxford 38655

K. E. Saxton, hydrologist, USDA-SEA-AR, in cooperation with the College of Agriculture Resea Center, Washington State University, Pullman 99164

M. L. Sharma, senior research scientist, CSIRO, Division of Land Resources Management, Wembl W.A. 6015, Australia; a (1977) visiting soil scientist with USDA-SEA-AR, Southern Plains Watershed Research, Chickasha, Okla. 73018

R. C. Sidle, soil scientist, USDA-SEA-AR, in cooperation with West Virginia Agricultural and Forestry Experiment Station, Morgantown 26506

R. E. Smith, research hydraulic engineer, USDA-SEA-AR, Watershed Hydrology Laboratory, in cooperation with the CSU Experiment Station, Colorado State University, Fort Collins 8052

A. W. Thomas, agricultural engineer, USDA-SEA-AR, Southern Piedmont Conservation Center, Watkinsville, Ga. 30677, in cooperation with College Experiment Stations, The University of Georgia, Athens 30602

CONTENTS

INFILTRATION EFFECTS OF SOIL AIR PRESSURE

R. M. Dixon

Water infiltration into soils involves displacement of soil air with water. Such displacement is usually manifested as a simultaneous exchange of surface water and soil air across the air-earth interface. For surface water to displace soil air, the pressure of upstream soil air must rise above the ambient atmospheric pressure. Several workers have observed water movement response to air pressure changes within laboratory columns of porous media (Powers, 1934; Horton, 1940; Free and Palmer, 1940; Peck, 1965; Adrian and Franzini, 1966; and Wilson and Luthin, 1963).

These column studies and capillary tube theory lead to several obvious generalizations. In short columns, air pressure rises more rapidly but to a lower maximum than in long columns. Similarly, in coarse porous media with large pores, air pressure rises rapidly but to a lower maximum than in fine media with small pores. Under a surface having a high-bubbling pressure, air pressure rises more slowly but to a higher maximum than under a low-bubbling pressure surface. The surface may lift or rupture to reduce air pressure where a high-bubbling pressure surface caps a short column.

Theoretical analyses of infiltration often neglect the effect of displaced air pressure on the advancing wetting front (Philip, 1958; Wilson and Luthin, 1963). The simplifying assumption is usually made that the air pressure component of soil water pressure is negligible compared to the matrix or capillary component. The idea is often expressed that soil macropores readily vent displaced soil air and thereby keep the pressure to negligible levels. The authors reporting these column studies suggest that two primary field conditions are conducive to rapid soil air pressure rise. These are a large water-saturated surface area and a small antecedent soil air volume. Thus, border and basin irrigation, large ground water recharge basins, and high intensity rainfall would favor development of displaced soil air pressure; whereas furrow, trickle, and low intensity sprinkler irrigation and low intensity rainfall would produce little or no soil air pressure. The rate of air pressure rise would be increased by a small initial displaceable air volume caused by high initial soil moisture or a shallow air barrier, or both, such as a water table, wet plow sole or pan, wet clayey subsoil, cemented soil layer, impervious rock stratum or any combination of these. Field infiltrometers and rainfall simulators do not wet a sufficiently large surface to cause measurable rise in soil air pressure, since the air displaced by infiltrating water can escape freely to surrounding dry soil. One somewhat rare exception would be where the infiltrometer frame extends downward into a soil air barrier.

The Committee on Soil Physics Terminology of the International Society of Soil Science concluded that soil air pressure was not important enough under field conditions to justify inclusion in their final report (ISSS Committee, 1963; Rose, 1966). Contrary to this conclusion, the air-earth interface AEI concept (Dixon, 1972) indicates that soil air pressure interacts with soil surface conditions to give an order-of-magnitude control over infiltration. This concept states that the AEI conditions, surface microroughness and surface macroporosity, interact hydraulically to control free surface water infiltration by regulating the flow of air and water in underlying macropore and micropore systems. During the past 5 years, the infiltration role of soil air, as envisioned by the air-earth interface concept, has been verified and reported in a series of papers (Dixon and Linden, 1972a, 1972b; Linden and Dixon, 1973, 1975, 1976; Dixon, 1975, 1977; and Linden et al., 1977).

The main contributions of these papers include the (1) conception and definition of a new infiltration parameter--the effective surface head--defined as ponded water head minus soil air pressure head; (2) further verification and refinement of the AEI concept; and (3) development of closed top and "closed bottom" infiltrometers, which can produce a realistic range of effective surface heads surrounding zero head taken as ambient atmospheric pressure head. The experimental results reported in these papers show clearly that soil air is a major component of natural infiltration systems, and that the soil air pressure effect on infiltration occurs principally within the macropore system. Thus, an infiltration model, to be useful, must consider both soil air and soil macropores. To assume that soil macropores take care of the soil air pressure problem, as theorists have done, is not in the interest of advancing our understanding, prediction, and control of natural infiltration processes. However, experimentally controlling or eliminating the air pressure effect (for example, side and bottom venting of soil columns) is often useful in isolating other components of infiltration system for independent study.

CRITICAL RESEARCH NEEDS

1. Further development of closed-top and "closed-bottom" infiltrometers of both the ponded-water and sprinkled-water types.
2. Determine the range of effective surface heads occurring naturally in all major soils.
3. Determine infiltration response of all major soils to the natural range in effective surface heads using both ponded-water and sprinkled-water infiltrometers having the best open-top or "closed-bottom" design, as determined by #1.
4. Relate the effective surface heads measured in #2 to the parameters in Kostiakov's equation.
5. Determine the effective surface heads associated with major land management systems.
6. Improve old and develop new cultural practices having appropriate effective surface head levels to achieve desirable land management objectives such as infiltration, runoff, erosion, and evaporation control for improved crop stands and greater and stabler crop yields.
7. Determine effective surface heads and soil surface geometries associated with optimal routing of irrigation and rainwater into the soil for maximum crop production.

CITED REFERENCES

Adrian, D. D., and J. B. Franzini. 1966. Impedence to infiltration by pressure build up ahead of the wetting front. J. of Geophys. Res. 71: 5857-5863.

Dixon, R. M. 1972. Controlling infiltration in bimodal porous soils; Air-earth interface concept. Proc. Second Symposium on Fundamentals of Transport in Porous Media. International Association of Hydraulic Research, International Society of Soil Science, and University of Guelph.

Dixon, R. M. 1975. Design and use of closed-top infiltrometers. Soil Sci. Soc. Amer. Proc. 39:755-763.

Dixon, R. M. 1977. Air-earth interface concept for wide-range control of infiltration. Annual Meeting of ASAE. Raleigh, N.C. Paper No. 70-2062.

Dixon, R. M., and D. R. Linden. 1972a. Soil air pressure slows water intake. Crops and Soils Magazine 24:19-20.

Dixon, R. M., and D. R. Linden. 1972b. Soil air pressure and water infiltration under border irrigation. Soil Sci. Soc. Amer. Proc. 36:948-953.

Free, G. R., and J. J. Palmer. 1940. Interrelationships of infiltration, air movement, and pore size in graded silico sand. Soil Sci. Soc. Amer. Proc. 5:390-398.

Horton, R. E. 1940. An approach toward a physical interpretation of infiltration capacity. Soil Sci. Soc. Amer. Proc. 5:399-417.

ISSS Committee. 1963. Soil physics terminology. International Soc. of Soil Sci. Bulletin 23.

Linden, D. R., and R. M. Dixon. 1973. Infiltration and water table effects of soil air pressure under border irrigation. Soil Sci. Soc. Amer. Proc. 37:94-98.

Linden, D. R., and R. M. Dixon. 1975. Water table position as affected by soil air pressure. Water Resour. Res. 11:139-143.

Linden, D. R., and R. M. Dixon. 1976. Soil air pressure effects on route and rate of infiltration. Soil Sci. Soc. Amer. Proc. 40:963-965.

Linden, D. R., R. M. Dixon, and J. C. Guitjens. 1977. Soil air pressure under successive border irrigations and simulated rain. Soil Sci. 124:135-139.

Peck, A. J. 1965. Moisture profile development and air compression during water uptake by bounded bodies: 3 vertical columns. Soil Sci. 100:44-51.

Philip, J. R. 1958. Physics of water movement in porous solids. Highway Research Board, Special Report 40, pp. 147-163.

Powers, W. L. 1934. Soil water movement as affected by confined air. J. Agric. Res. 49:1125-1133.

Rose, C. W. 1966. Agricultural physics. Pergamon Press, New York, N.Y.

Wilson, L. G., and J. N. Luthin. 1963. Effect of air flow ahead of the wetting front on infiltration. Soil Sci. 96:136-143.