

Water Movement in Soils

by DR. WALTER H. GARDNER

Professor Emeritus, Washington State University

AS A LIQUID or vapor, water is nearly always moving in the soil. It moves downward after rain or irrigation. It moves upward to evaporate from the soil surface. It moves towards and into plant roots, and eventually into the atmosphere through transpiration. And during the night, when transpiration is greatly reduced, water moves from moist soil between roots into soil adjacent to absorbing roots that has dried during the previous day.

Horizontal movement also is important, as, for example, when water moves from an aeration hole. Water movement can be in any direction, depending on conditions.

Water flows through the open pores between soil particles. In an ordinary silt loam, for example, half the soil volume is pore space. Water and air share this pore space. For most plants it must be possible for air from the root zone to exchange with air from the surface. Air from the root zone is laden with carbon dioxide, as a result of metabolism in the roots.

Pores in different soils vary in size and number. Silty and clayey soils



Dr. Walter H. Gardner

generally have smaller but many more pores than sandy soils. Because of the number of pores, silty and clayey soils filled with water contain more total water than sandy soil with all its pores filled.

Some of the water in soils with fine pores is held so tightly the plant can't absorb it. Even so, the amount in these

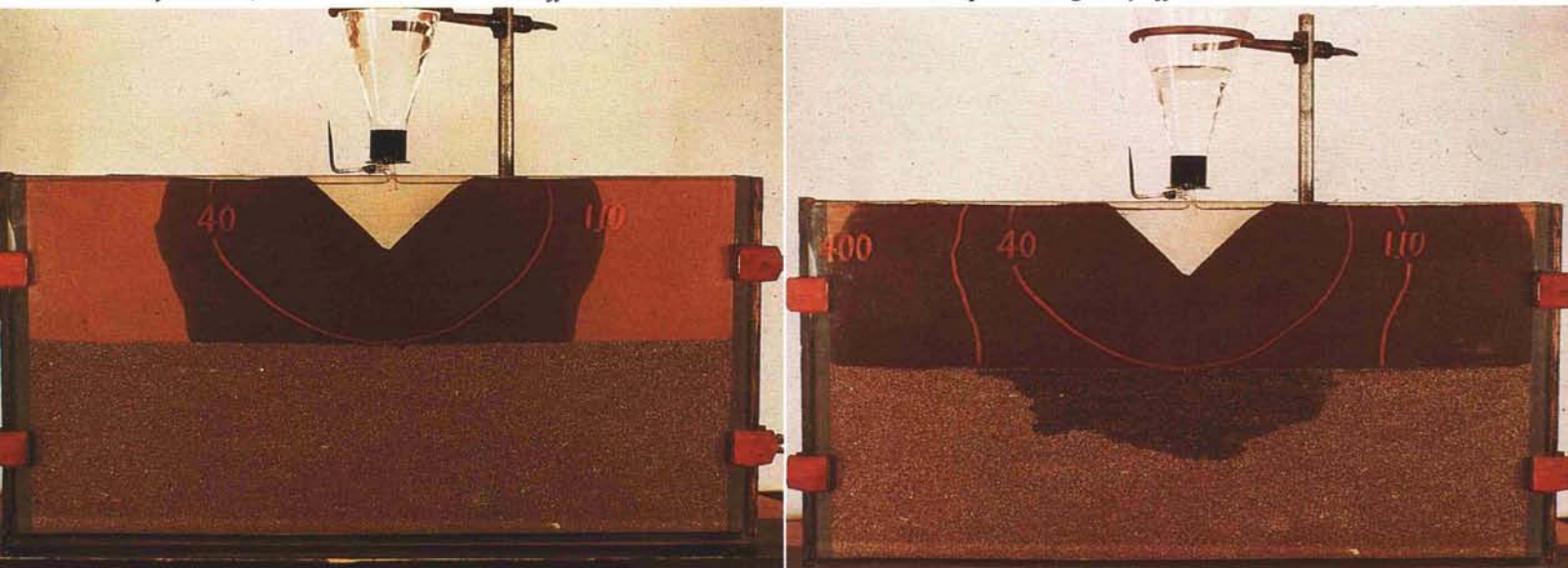
soils is greater than the amount available to the plant in soils with large pores.

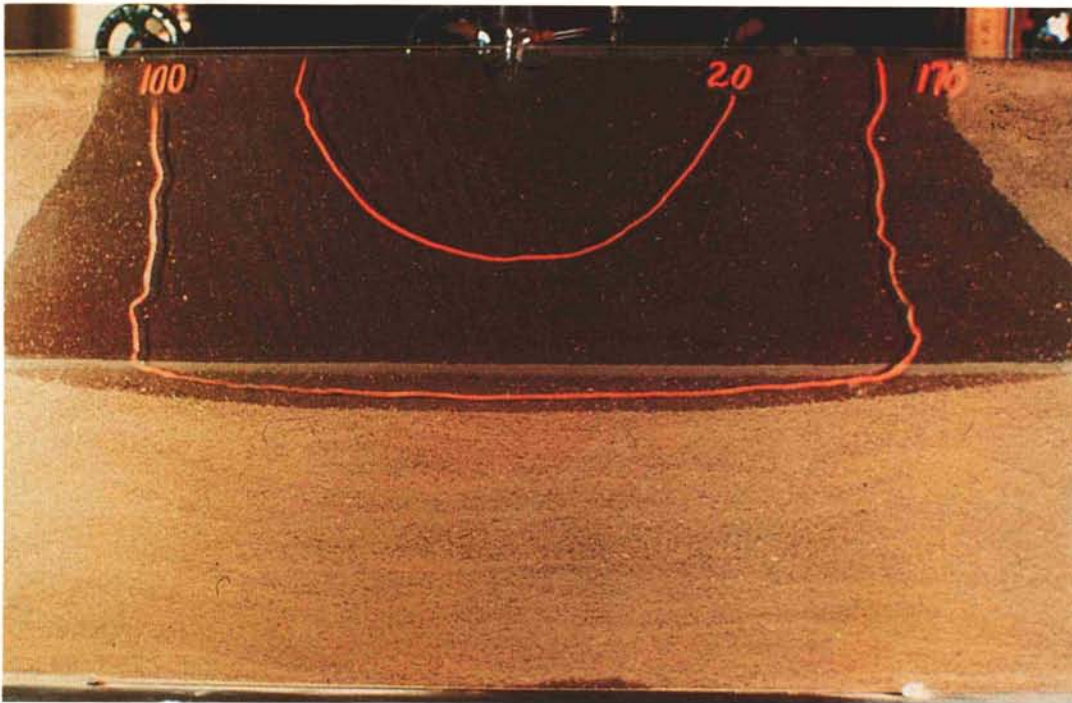
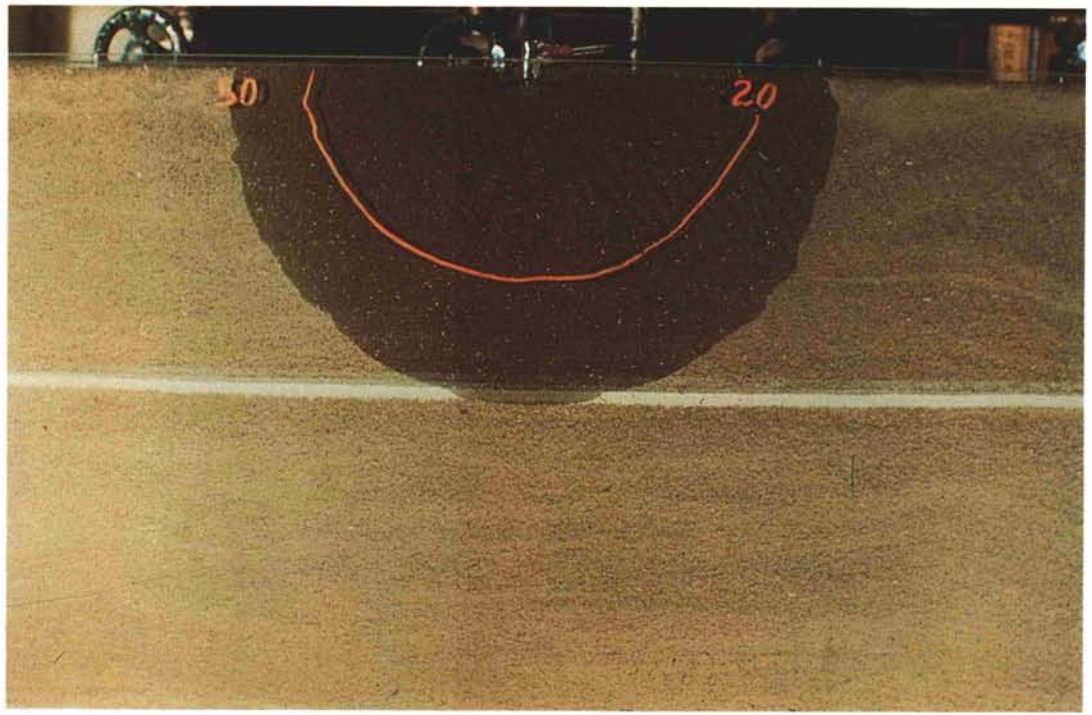
Two major forces move liquid water through the soil pores; these forces are gravity and adhesion. The movement of water is entirely different under these two conditions. To understand the differences, let me first tell you about surface tension of liquid water.

You have seen raindrops or drops from a dripping tap, and you probably noticed they are roughly spherical, with a positive radius of curvature. They are held in this shape by a force called surface tension, which acts at the air-water interface in a somewhat similar manner as a rubber balloon, opposing a positive pressure inside of the droplet. Now, much of the water you see — water from a tap, water in a lake or stream, or water in the cup you drink from — is under positive pressure. This is how most people think of water. Water under positive pressure moves in response to the pressure of a column of water or by gravitational forces.

Now, let me discuss another class of water you ordinarily think of under the term moisture. You are equally familiar with this water, inasmuch as it is the

In a layered soil, water will not move into a different textured soil until saturation takes place and gravity affects water movement.





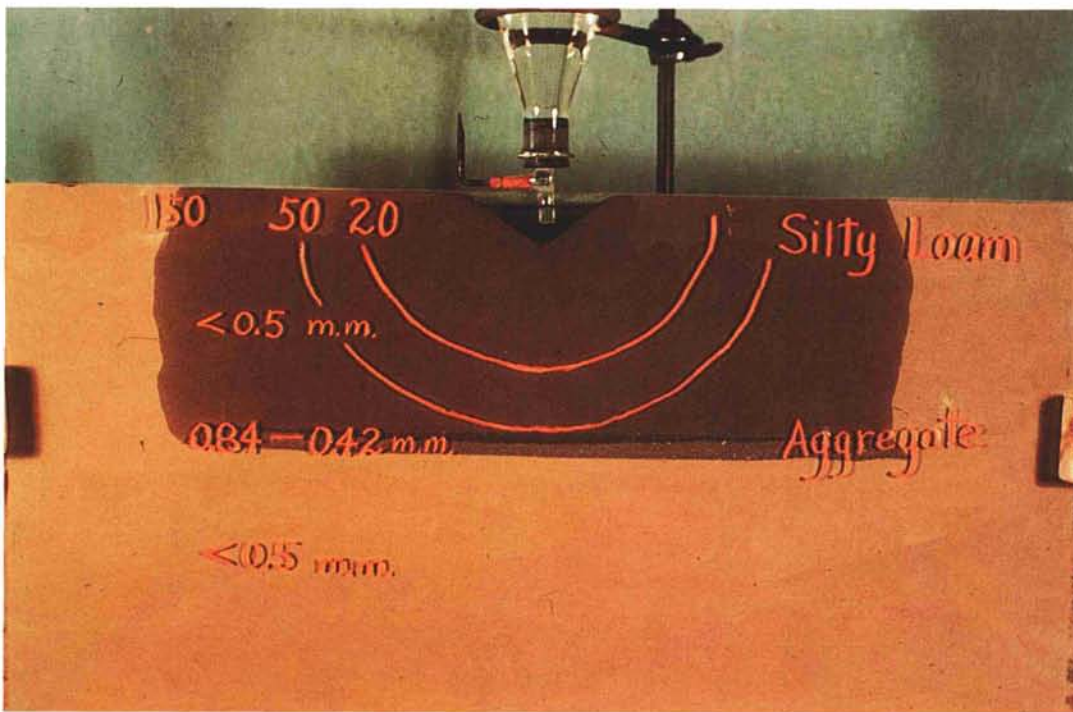
When water reaches the clay, the very fine pores of this layer resist water flow. Although water does pass through the clay, its penetration is so slow that water tables often build up above the clay. Some hardpans act similarly.

moisture in, for example, a dish-drying towel, material of your shirt when you perspire, and the soil when it is not saturated. It is the water that is said to be absorbed by a porous material, and it is water that exists with a negative curvature in the air-water interface as you would observe it under a high-powered microscope. This water is under negative pressure, contrasted to the water of the raindrop, where the air-water interface is positive and the

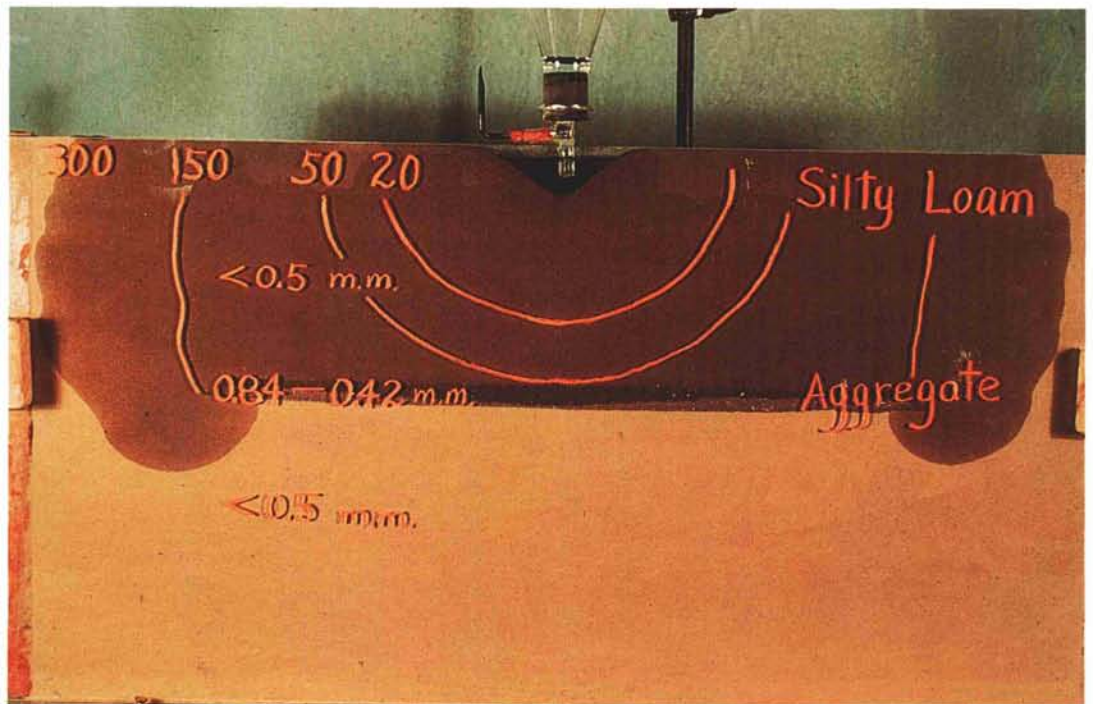
pressure is positive. Water in porous materials under negative pressure must be pulled along by attractive forces that exist between water and the walls of the porous material associated with it, and forces in a negative air-water interface that is always present. The best example of capillary water is water pulled upward into a small tube by adsorptive and cohesive forces. The absorptive property of blotting paper is a good illustration. Adhesion — to-

gether with cohesion, which causes water molecules to hang together — makes water move on particle surfaces and through the finer pores.

The differences in the positive and negative forces that move water in the two cases make huge and often dramatic differences in phenomena that involve water. Most phenomena involving water movement under positive pressure take place in pipes and in streams and ditches. Considerable water is usually moved in



Any change in soil porosity encountered by a wetting front affects water movement. In these photographs, a layer of coarse soil aggregates acts much like a layer of sand, with one important difference: water can move through the interior of the aggregates themselves. But the relatively small number of contacts between the aggregates limits the amount of water that actually moves through this layer. Only when the soil is nearly saturated does the water move rapidly through the soil aggregate layer. Saturation was not reached in this test.



this condition. By contrast, movement in porous materials under negative pressure takes place in thin films, and consequently the quantity of water moved with a similar size of moving force is a small fraction of that where a positive pressure exists.

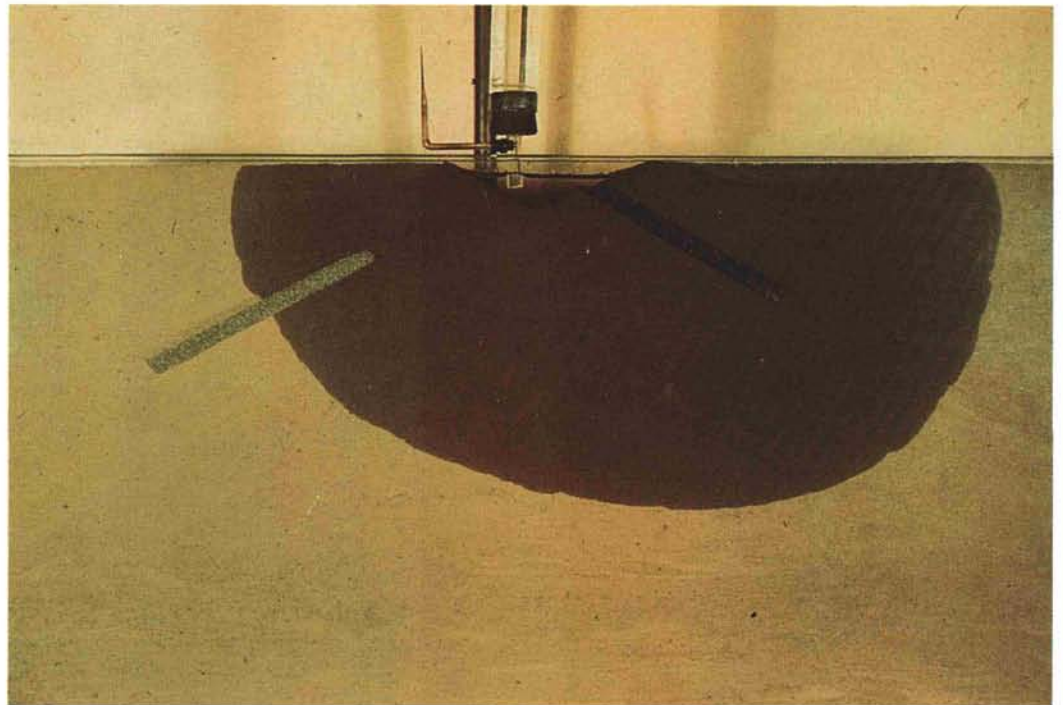
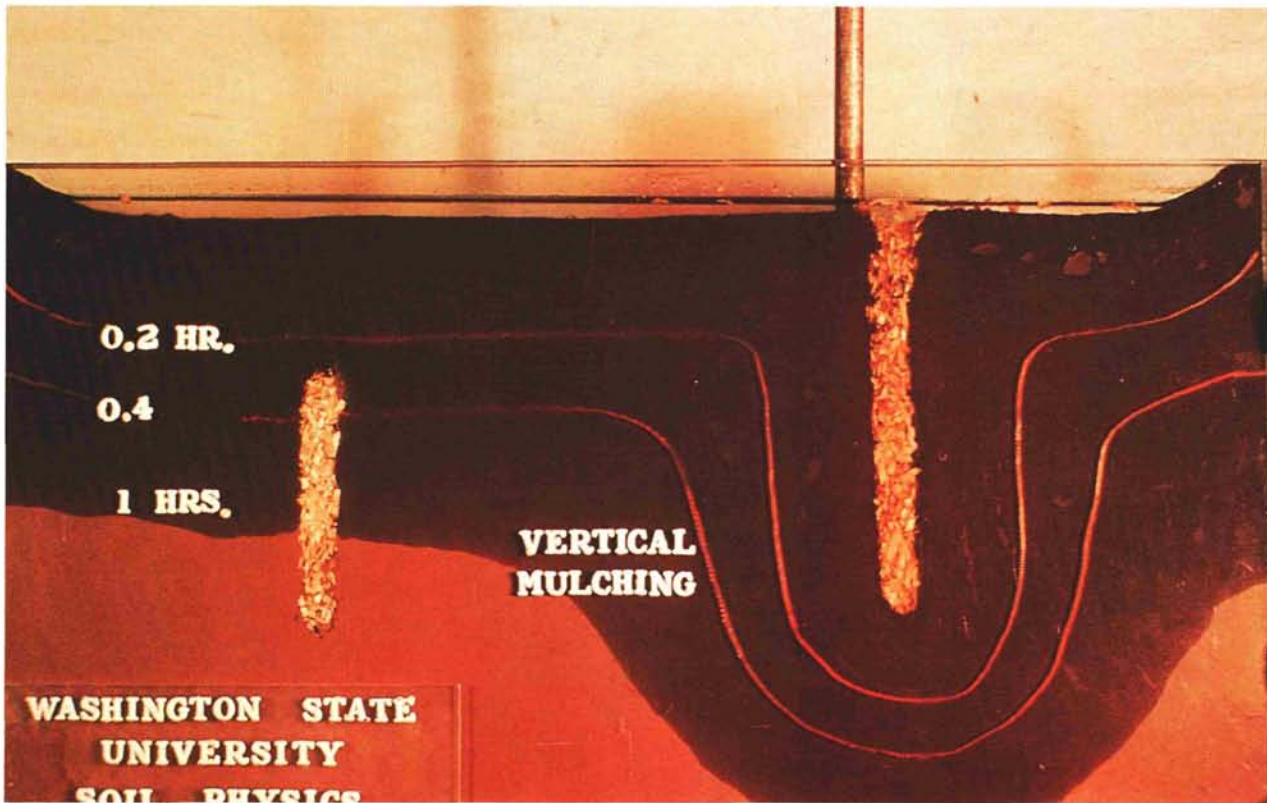
Water moves until the forces balance, at which point the curvature of air-water interfaces is the same, except for some vertical differences that exist because of gravity. If the soil is not uni-

formly homogeneous, the portions of the soil that have the smallest pores retain water most strongly.

In stratified soils — soils with various “layers” such as those recommended in the USGA Green Section Specifications for Putting Green Construction — the size of the pores in the strata affect water flow. If an advancing wetting front encounters fine materials, the resistance in the extremely fine pores may slow the movement. But the water

nevertheless continues to move. If the wetting front encounters coarse materials, water movement stops until the soil becomes nearly saturated.

Stratified soils also tend to hold more water for plant use than uniform soils. Since the different layers slow the movement of water, more remains in the root zone. A sandy, droughty soil can thus be made to hold more water, and yet will drain rapidly when it is saturated.



(Top) Here, deep vertical channels are cut in the soil and filled with coarse material. If the channels remain open to the surface, the large pores in the coarse material take free water from rain or irrigation and transmit it deep into the soil. Then it is absorbed by the soil. If the channels are not open to the soil surface, vertical mulching does little good. Holes left in the soil by angleworms, rodents, or aeration act like vertical mulch channels. If they remain open to the surface and exposed to free water, they carry water readily.

(Above) Note channel open to the surface rapidly moved water into the soil. Buried channel has no effect.

The same amount of water was applied to each of three soils. The clayey soil holds water in a smaller column than loam or sandy soil. This indicates that clay soils can hold more total water than loams or sands. Under irrigation, the poor water-transmitting properties of such soils make them less desirable than sandy soils.



These principles of how water moves in soils have been incorporated in the construction of USGA Green Section greens. The effect on water penetration of such practices as a physical soil analysis, off-site uniform soil mixing, adequate soil depth, a sand and gravel layer, tile lines, mechanical aeration of the putting surface, and the importance of keeping vertical aeration channels

open to the surface through the use of sand cannot be overemphasized.

The knowledge of these principles and their application are essential to proper management of turf areas.

EDITOR'S NOTE: This article is based on direct excerpts of Dr. Walter Gardner's talk and film presentation during the 1988 USGA Educational Program in

Houston and from an American Society of Agronomy 1979 reprint, "How Water Moves In Soil," by Dr. Gardner.

For details regarding the 27-minute, 16mm, color, time-lapse, sound motion picture film or video cassette, please contact your regional Green Section office or the Agronomy Club, Department of Agronomy and Soils, Washington State University, Pullman, WA 99164.