How water moves in the soil

Five pages of photographs reveal the great diversity in one of the most commonplace phenomena in agriculture

BY WALTER H. GARDNER

WATER—as a liquid or vapor—is nearly always moving in the soil. It moves downward following rain or irrigation. It moves upward to evaporate from the soil surface, or into plant roots and eventually into the atmosphere through transpiration. Horizontal movement also is important as for example when water moves out from an irrigation furrow. 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 generally have smaller pores but many more pores than sandy soils. Because of the number of pores, when silty and clayey soils are filled with water these soils 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 that it is unavailable. Even so, the amount that is available in these soils

Walter H. Gardner is a soil scientist at Washington State University. This article is adapted from a two-part series that appeared in the October and November 1962 issues. Because of a steady demand from teachers and others, the issues have become virtual collectors' items. The editors feel that these dramatically illustrated basic concepts are worth repeating.

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

Two major forces move liquid water through the soil pores: gravity and adhesion. Gravity is most important in saturated soils. It causes a downward force on water. When a soil is near saturation, the large pores are filled and water moves rapidly through them.

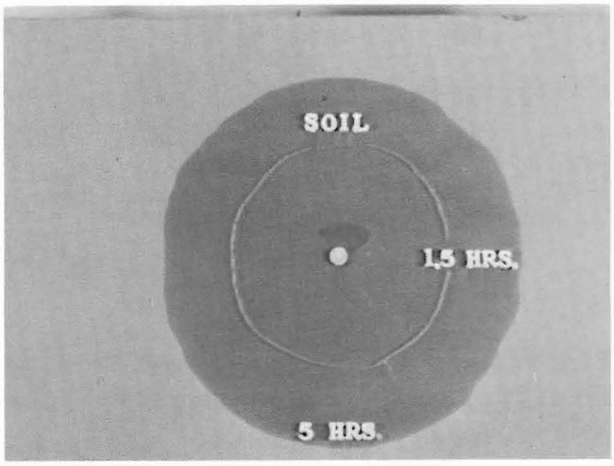
When a soil is not saturated, the larger pores are empty and contribute little to flow. In the unsaturated soils in which most crops grow, the major force moving water is adhesion. Adhesion—together with cohesion, which causes water molecules to hang together—makes water move on particle surfaces and through the finer pores. These are the same forces that make water rise in capillary tubes and that account for the absorptive properties of blotting paper.

Water moves until the forces balance, at which point water films on soil particles are uniform in thickness throughout any homogeneous soil except for some vertical differences that exist because of gravity. If the soil is not uniform or homogeneous, the portions of the soil that have the smallest pores retain water most strongly.

In stratified soil—soil with various "layers"—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.

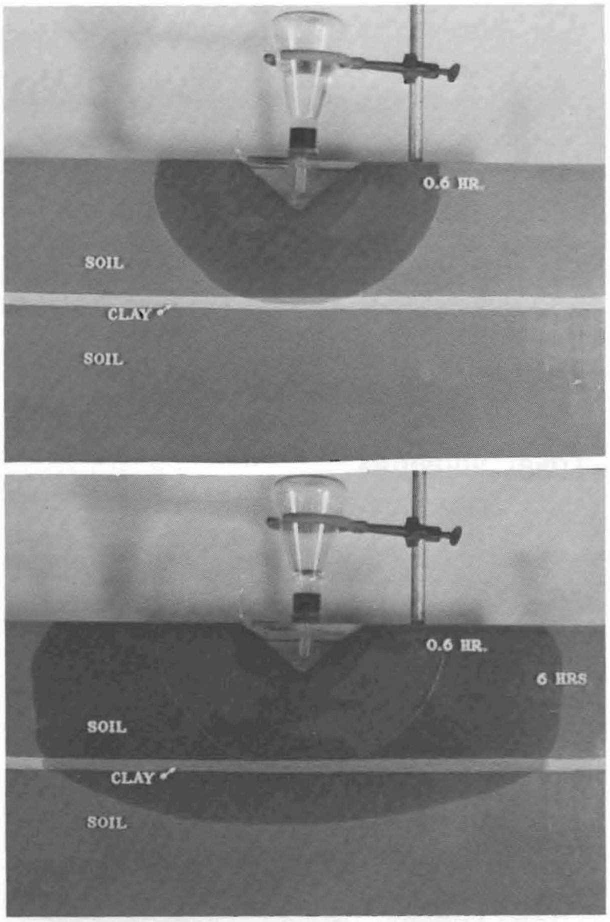
Stratified soils also tend to hold more water for plant use than uniform soils. Since the different layers slow the movement of water, more remains in the root zone.

The photographs on these pages show some basic principles of water movement using artificial soil profiles.



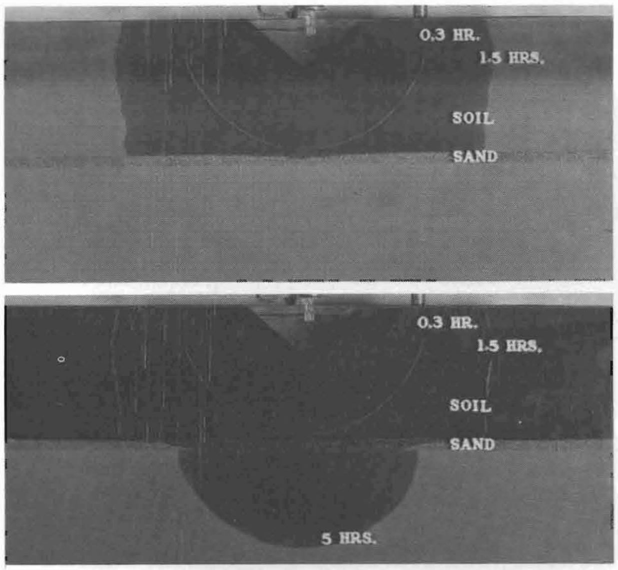
Uniform or homogeneous soils

Water was added to the center of this dry homogeneous soil. Under this unsaturated condition the water moves out almost equally in all directions. Gravity has only a small effect as indicated by the slightly greater downward wetting. Under saturated conditions, or as saturation is approached, gravity begins to play a much greater role in water movement.



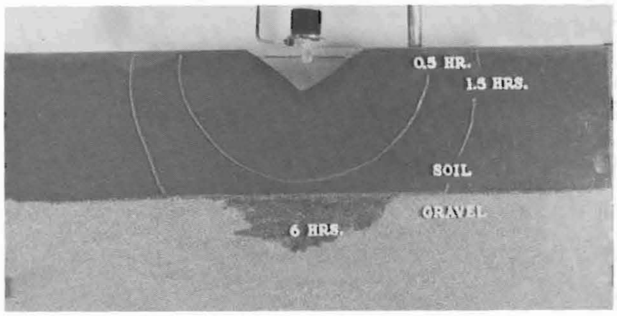
Clay layer

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 plow pans act similarly.



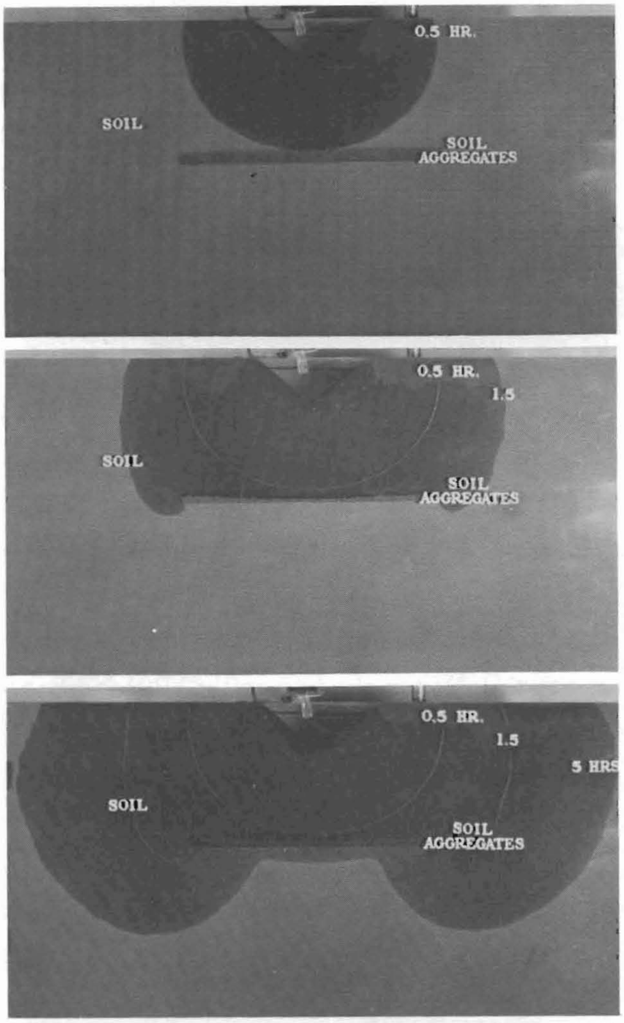
Sand layer

When water passes through fine soil and reaches a layer of coarse sand it stops until enough water accumulates to nearly saturate the fine soil. When the fine soil is almost saturated the water readily moves from it into the large pores of the sand. This is much the same as adding water to blotting paper. Only when the blotting paper is near saturation does it begin to drip.



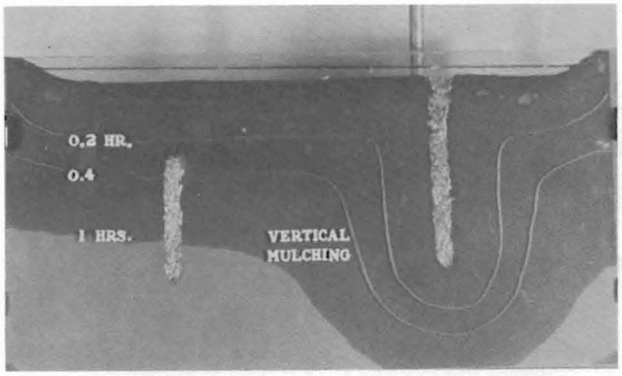
Coarse sand or gravel subsoil

Fine soil overlying a coarse sand or gravel subsoil must become very wet before water will move down through the large pores of the subsoil. Under these conditions the overlying soil holds up to two or three times as much as it would if the coarse subsoil were not present.



Layer of coarse aggregates in fine soil

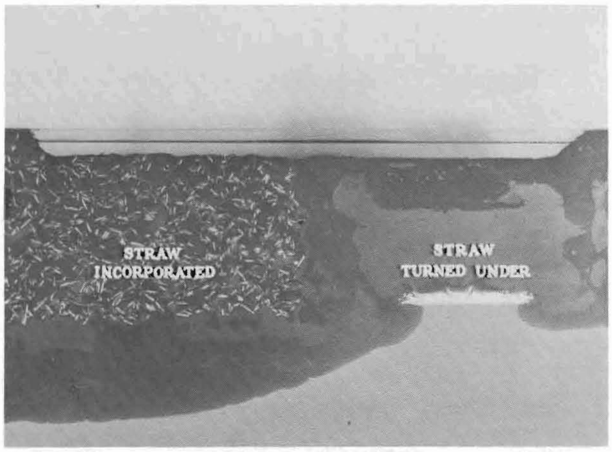
Any change in soil porosity encountered by a wetting front affects water movement. In these three photographs, a layer of coarse soil aggregates acts much like a layer of sand, with one important difference: water can move through the interior of the aggregates themselves. But the relatively small number 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.



Vertical mulching

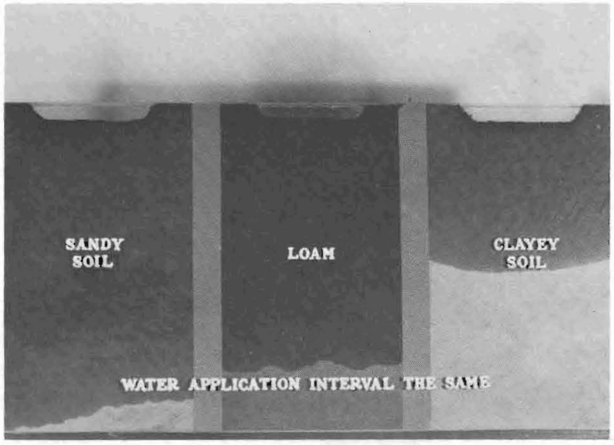
Here, deep vertical channels are cut in the soil and filled with chopped organic matter. If the channels remain open to the surface, the large pores in the organic matter take free water from rain or irrigation and transmit it deep into the soil. Then it is absorbed by the soil. If the channels are not open to the soil surface, vertical mulching does little good.

Holes left in the soil by angleworms, rodents, or decaying crop residue act like vertical mulch channels. If they remain open to the surface and exposed to free water, they carry water readily. These open channels or holes also help soils with poor aeration by permitting the exchange of gases between the soil atmosphere and the air above.



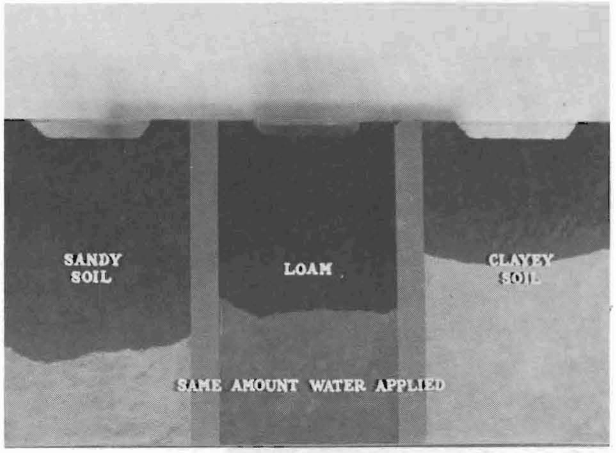
Straw or organic matter layer

Straw plowed under and left in a layer forms a barrier to the downward movement of water much like a layer of sand or coarse soil aggregates. If the straw is mixed with the soil, its decomposition releases substances which help to maintain the open porous structure created by plowing. Where the porous structure extends to the soil surface the large pores speed downward movement of water.



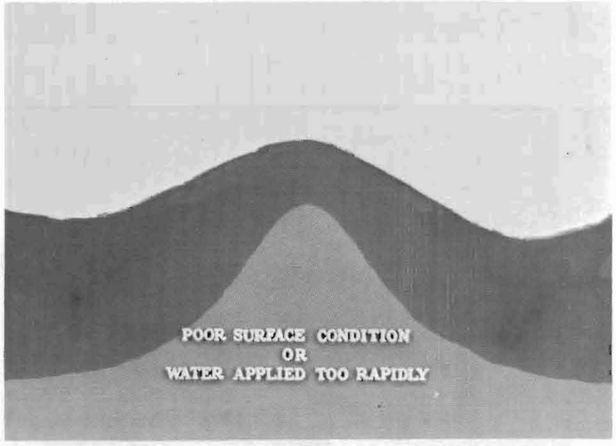
Soil texture and infiltration

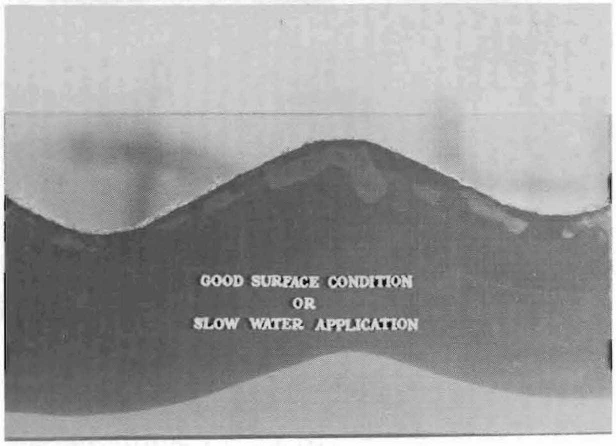
Water was applied to three soils at the same time and rate. Infiltration and the advance of wetting front is more rapid in sandy soil than in either loam or a clay soil.



Soil texture and water-holding capacity

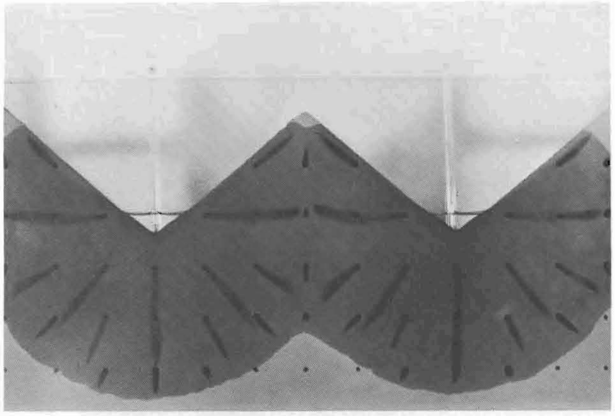
The same amount of water was applied to each of three soils. The clayey soil holds the water in a smaller proportion of its volume than either the loam or the sandy soil. This indicates that clay soils can hold more total water than either loams or sands. Because they hold more water, fine silt loams and clay loams are likely to be better soils for dryland farming than coarse sandy soils. But under irrigation the poor water-transmitting properties of such soils make them less desirable than sandy soils.





Uneven surface

If water is applied to rolling or hilly terrain more rapidly than it can infiltrate, it runs off the high spots and accumulates in the low spots where it penetrates to greater depths. If the water application rate equals the infiltration rate, the soil wets uniformly. Surface conditions favorable to high infiltration rates permit higher application rates with uniform wetting.



Soluble fertilizers move with water

Dye tracers indicate the direction of water movement in irrigation furrows. Water and soluble fertilizers move almost radially away from the point where water was applied in the furrows. After the wetting fronts join, the direction of flow changes slightly. Above the water level of the furrows, the movement is upward toward drier soil. Below the free water level, soluble materials move downward. In addition, evaporation from the soil surface causes an upward movement of soluble materials in the soil solution.

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A 27 minute, 16 millimeter color, time-lapse **motion picture film** with sound and 35 millimeter color slides illustrating the principles shown are available from the Agronomy Club, Department of Agronomy, Washington State University, Pullman, Wash. 99163.