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SOIL AIR PRESSURE EFFECTS ON ROUTE AND RATE OF INFILTRATION[1]

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Abstract

One centimeter of 0.1% methylene blue solution was infiltrated into soil with various constant soil air pressures beneath the wetting surface to measure flow into and through soil macropores. Flow was increasingly impeded as soil air pressure increased from 0 to 5 mbars. Infiltration rates during the first 3 min of wetting were decreased by an order of magnitude with 5 mbars of air-back pressure.

***Additional Index Words:* macropores.**

WATER INFILTRATION into field soil during the first few minutes after flooding is often extremely rapid. This rapid infiltration is usually not considered in mathematical analysis of infiltration because of the lack of uniformity within the soil and because of lack of knowledge about the nature of the flow (5). Considerable qualitative information indicates that "pipe" flow occurs (3), however, few measurements of pressure potentials and pore sizes are available for a mathematical analysis.

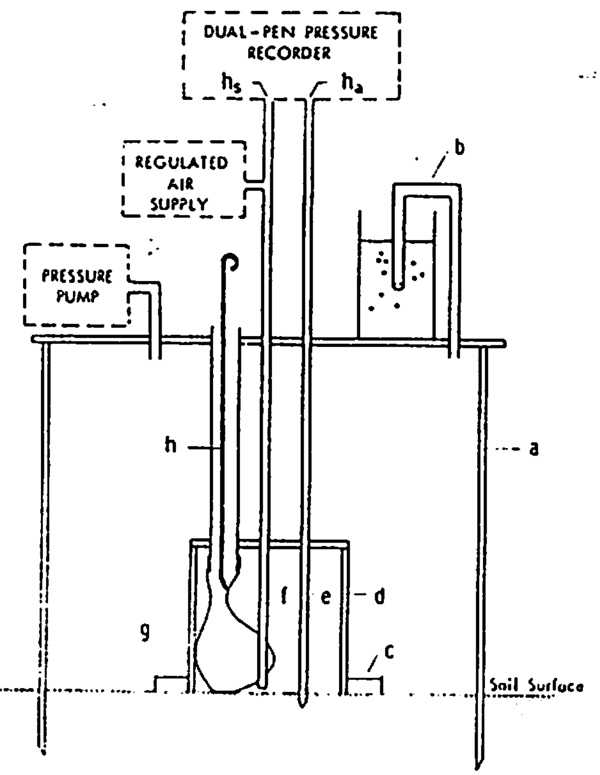

Fig. 1—Infiltration device used to simulate soil air pressure: (*a*) air pressure ring, (*h*) pressure regulator, (*c*) saturation paste seal, (*d*) water ring, (*e*) air pressure access tube, (*f*) bubbling tube, (*g*) water filled balloon, and (*h*) balloon rupture rod. (h_s is depth of ponded water and h_a is soil air pressure)

Dye-stained flow routes have been used to describe soil macropores and macroporous flow. Ritchie, et al. (7), using fluorescein to stain routes, reported irregular wetting patterns in a shrinking clay soil, while staining was extensive along the interface of natural cracks. Aubertin (1), using malachite green found extensive staining along old root channels and animal burrows in a forest soil. Reynolds (6), using fluorescent compounds, observed irregular wetting patterns in a forest soil. Ehlers (4) stained earthworm channels to demonstrate their contribution to infiltration. Dixon and Peterson (5) reported macroporous flow deduced from considerable indirect evidence. In this manuscript we report observations of staining as direct evidence that macroporous flow occurs and that small soil air pressures block water entry into macropores and thereby greatly reduce infiltration (2).

Materials and Methods

A 0.1% methylene blue solution was infiltrated into two naturally structured soils under various soil air pressures. Infiltrometer equipment, shown schematically in Fig. 1, was used to control air pressure and measure infiltration. Soil air pressures were created by pumping air into the soil through the outer ring (*a*). Constant air pressures from 0 to 5 mbars were controlled by adjusting the airflow rate and the bubbler regulator (*h*). A volume of methylene blue solution equivalent to a 1-cm depth was placed in the balloon (*g*). The balloon was broken, thus allowing solution to flood the surface and the air above the ponded water to escape and its pressure return to atmospheric. Thus, the desired constant soil air pressure, h_a, under a flooded surface was established rapidly.

Soil air pressure, h_a, at a single point, 1 cm below the soil surface, was determined with a bellows-type recorder and a small (6.2-mm diam) access tube (2). Infiltration was determined by recording the change in depth of ponded water with a bubbling apparatus and calculating the depth-decline rates at 9.4-sec intervals. During infiltration methylene blue dye was deposited from solution along macropore walls, while the soil removed the color over short distances during flow through micropore regions. Thus although a considerable mass of soil may have been wet, only routes of rapid movement were stained. Staining patterns were observed by excavating, at about 1-cm intervals, vertical faces of the cross section under the infiltrometer. Infiltration and excavation were duplicated for each air pressure. An additional set of infiltration experiments was conducted using undyed water.

Infiltration studies were conducted at two sites on an East Fork loam soil. Site 1 was under a 3-year-old alfalfa (*Medicago sativa* L.) stand, whereas site 2 was under a dead bluegrass (*Poa Pratensis* L.) sod which had not been irrigated for several years and had somewhat less macroporosity. Macropores at these sites were about 1 mm in diameter or width and thus are more common in soils than the large macropores studied by Aubertin (1), Reynolds (6), and Ritchie et al. (7).

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Results and Discussion

Infiltration rates decreased with increasing soil air pressures (Fig. 2). Infiltration rates for the higher soil air pressure treatments (Fig. 2) are the arithmetic average of the values calculated at 9.4 sec intervals during the first 3 min of infiltration. For the lower soil air pressures they are the average for 1-cm infiltration which lasted < 3 min. Infiltration of 1 cm of dye water took < 1 min at zero soil air pressure treatment and > 1 hour at 5 mbars pressure. The dye solution infiltrated like undyed water since infiltration rates were not significantly different for the two liquids.

Stain penetration decreased with increasing soil air pressure. The maximum depths of stain penetration at either site were 30, 50, 13, 10, 2.5, and 2 cm for soil air pressures of 0, 1, 2, 3, 4, and 5 mbars, respectively. The depths of extensive staining were limited to 15, 10, 2, 1.5, 1.5, and 0.5 cm for the same respective soil air pressures. Staining was considered extensive when there were at least six stained areas within a circular frame with a 180 cm² area. The observed staining pattern of the macropore space during low soil air pressure infiltration was extremely irregular. Only earthworm (*Lumbricidae L.*) burrows could be distinguished easily since their walls stained uniformly and intensely (Fig. 3). Earthworm burrows often had a network of much smaller pores branching out laterally in an irregular pattern. Staining was observed near many very small roots of weed seedlings to a 1- to 5-cm depth. Larger roots never stained below about 5-cm depth, except when an earthworm burrow was next to the root. The soil volume surrounding alfalfa crowns was stained throughout, reflecting an interconnected net of macropores in this region. These soils generally did not have large cracks, but many small cracks or structural cleavages also caused an extensive mass of soil to be stained.

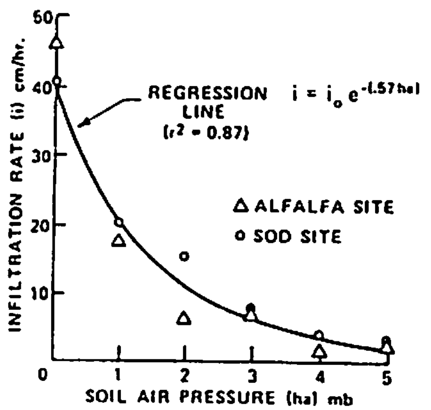

Fig. 2—Infiltration rate as a function of soil air pressure. Each point is the average of duplicate events.

Infiltration rates and stain penetration decreased as soil air pressures were increased and macroporous flow impeded. Impeding macroporous flow forces water to enter the soil through more microporous and tortuous routes and thus at slower infiltration rates. In the microporous flow routes the solution is close to soil particle surfaces so that water and solutes can interchange between entering and stored water and the soil particle surfaces. In the macroporous flow routes the bulk of the solution is at some distance from soil particle surfaces so that water and solute interchange is less. The difference between microporous and macroporous infiltration thus has significance in depth of water and solute penetration, leaching solutes from the soil, and soil water storage with depth. Macroporous flow was impeded by soil air pressures in this study but in nature it may be impeded by soil air pressure, surface seal development, or non-ponded infiltration.

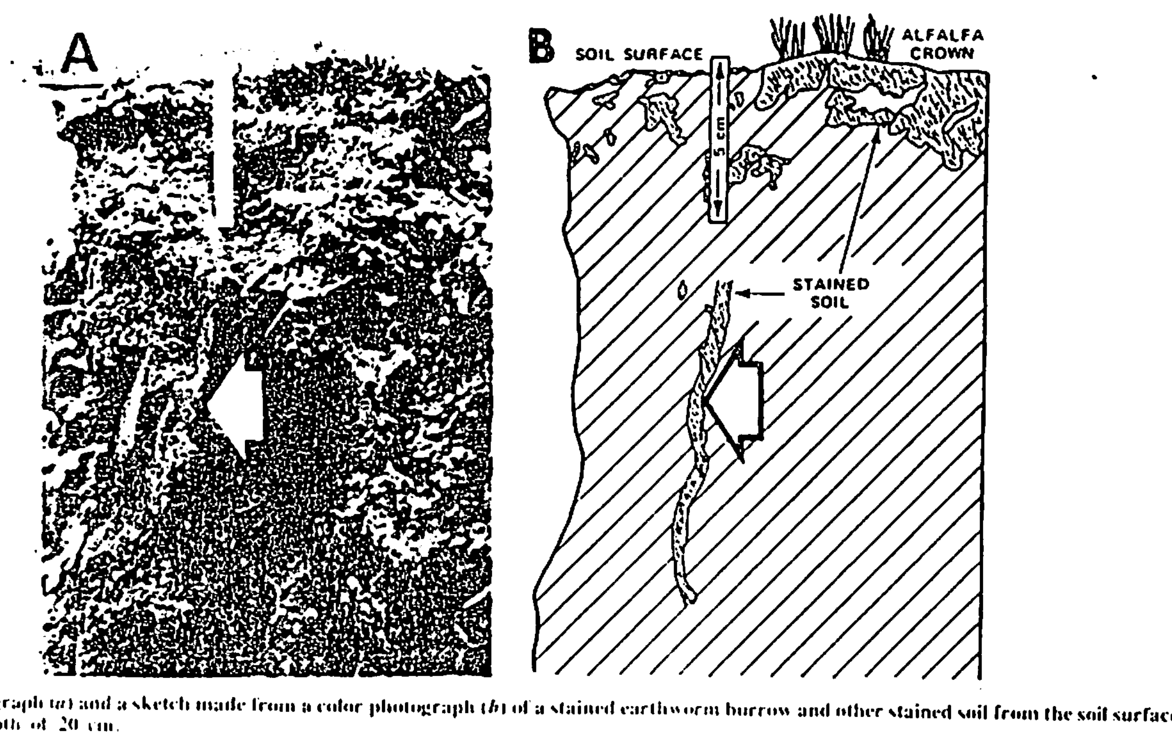

Fig. 3—A photograph (a) and a sketch made from a color photograph (b) of a stained earthworm burrow and other stained soil from the soil surface down to a depth of 20 cm.

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