MOVEMENT OF WATER THROUGH SOILS IN RELATION TO THE NATURE OF THE PORES

W. R. Nelson and L. D. Baver

THE soil is a complex porous system which is made up of various-sized pores. Not only does a wide variation exist between soils as to the distribution and amount of a particular size of pore, but also the porosity relations of a given soil change from one season to the next. Several investigators (2, 4, 8) have suggested the idea that the size distribution of pores should be directly related to soil structure and to definite soil physical properties. As yet, however, very little has been accomplished as to isolating those relationships.

The disposition of the infiltrated water is governed by the nature of the pore space. The water may be retained either in the smaller pores and at contact points of the particles, to be used in part by the plants, or the water may pass through the soil. The movement of the water out of the soil is very necessary for proper aeration conditions for the roots. The volumes of liquid and gases present in a given soil are complementary to each other and are affected by such factors as precipitation, humidity, plant growth, and other conditions present in the soil itself.

Haines (5, 6) has visualized the cellular configuration of the soil pore space and indicates that there are maxima and minima cross-sectional areas throughout the pore volume. In other words, large pores are connected to other large pores by narrow constrictions or necks. He states that in order for a saturated pore to be drained, it is necessary to apply a tension great enough to pull the meniscus through the smallest opening of the pore. Since this has never been proven experimentally, it was decided to make the study of Haines' concept one of the objectives of this investigation.

Hence, the first objective of this paper is to give a picture of what actually happens in the drainage of pores; the second is to show the relation of pore size to percolation rate.

EXPERIMENTAL PROCEDURES

The method used in this investigation is based on the capillary forces in the sand or soil system. It depends upon the removal of water by the application of a reduced pressure on one side with atmospheric pressure on the other. Theoretically, the maximum pressure differential which can be applied is one atmosphere or approximately a pF of 3.0. Actually, however, the differential possible is less. A pF of 2.75, equivalent to 563 cm of water, was the highest used in this study.

An apparatus was necessary in which the tension on a system could be adjusted to that desired and then kept constant. The outfit finally constructed resembled, in general, the ones used by Bradfield and Jamison (2) and Learner and Lutz (7).

In this study seven quartz-sand separates were used. They were 20-40, 40-60, 60-80, 80-100, 100-150, and 270-300 mesh and were separated by dry sieving. It was almost impossible to secure absolutely uniform separates in this manner since even after long periods of shaking a few sand grains of other sizes came through.

The tension-moisture curves were determined first on each of the individual sand separates. The cylinder was clamped to the base and the sand was poured in. It was necessary to tap the base about twenty times with a small block of wood in order to secure more even packing. The cylinders were filled so that the surface of the sand was flush with the top when the system was saturated.

A method was developed to demonstrate that sand separates having different average pore sizes do not drain at the same tensions. The separates drain when the tension necessary to pull the air-water interface through the entire system is reached. The brass cylinder was divided into four vertical quarters by the use of a snugly fitting metal divider. The divider was made of two 3-inch X 3-inch squares of heavy tin with a slit cut halfway up the middle of each square. They were then fitted together, soldered, and squared up. The separates used were 20-40, 60-80, 100-150, and 270-300 mesh; a different separate was put in each quarter. In this manner each separate had contact with the plate so that each could drain separately. Equal volumes of these four separates were then mixed together by rolling on a paper. A pF curve was run on this system to demonstrate the effect on the tension-moisture curve of filling the spaces between the larger particles with smaller ones.

In order to check Haines' concept, tension-moisture curves were determined on cylinders containing different layers of sand. Various arrangements of fine and coarse layers were used. Red pencil marks were placed around the inside of the cylinder at the level to which the sand separate was supposed to come in order to facilitate the filling of the cylinder. Tracing cloth was used to keep the layers apart. The sizing was dissolved out in hot water and discs just large enough to fit inside the cylinder were cut. When a fine layer of sand was used above a coarse layer, it was necessary to pack the upper one rather carefully to prevent air from being drawn through before the pores characteristic of that size separate began to drain. After the final tension measurement had been made, the layers of sand were separated and the amount of moisture was determined in each layer.

---

1 Contribution from the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio.
2 Research Assistant and Associate in Agronomy, respectively.
3 Figures in parenthesis refer to "Literature Cited", p. 76.