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NOTES

WATER RELATIONS OF FRITTED CLAY[1]

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ABSTRACT

Experiments and calculations were performed to characterize the water relations of fritted clay, a material which has been found suitable for growing experimental plants. Its dry bulk density is 0.67 kg/liter, particle density 2.50 kg/liter, total porosity 0.73, and saturated hydraulic conductivity 9.5 × 10^{-4} m/sec. The desorption relation was measured and the unsaturated hydraulic conductivity as a function of water content was calculated. Much water drains from the saturated material by gravity. After drainage from commonly used containers, the material holds 0.31 by volume of plant-available water, and has an air-filled porosity of 0.28. Its water relations are excellent for plant growth purposes.

Additional Index Words: **rooting medium, aeration porosity, plant-available water.**

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Fritted clay is a granular material made by firing coarsely-milled, dry clay in a rotary kiln. We have found it suitable as a medium for growing plants for the following reasons. The material has a relatively low dry-bulk density, is noncohesive, drains very rapidly, retains a large quantity of plant-available water, appears to be chemically inert, and can easily be washed off the roots. Its use as a rooting medium was suggested to us in 1975 by Dr. J. H. Silsbury of the Waite Agricultural Research Institute at Adelaide, Australia. The purpose of this note is to describe the water relations of the material in detail.

Materials and Methods

Fritted clay is made by a number of companies for the commercial trade and is sold as sweeping compound or pet litter. The material we used is sold as Absorb-N-Dry,[3] and comes from a shallow clay pit in Flatonia, Texas. Before firing, the clay consists largely of smectite, with small amounts of kaolinite, quartz, and probably crystobalite.[4] The fired product is mostly in the form of granules 1-2 mm in size with some fines. Before use, the fines were washed out with distilled water.

The desorption relation was obtained with the pressure cell method (Reginato and Van Bavel, 1962), using gas pressures from 0 to 100 kPa and with the pressure plate method (Richards, 1965), using gas pressures from 100 to 1,500 kPa (1 kPa = 10 mbars, 100 kPa = 1 bar). Pressure cell measurements gave the volumetric water content for 30 values of pressure, using four or five replications. Pressure plate measurements gave the gravimetric water content for nine values of pressure, using seven or nine replications.

The dry bulk density was obtained from rings of known volume filled with the wet material, in 10 replications. These values agreed with those obtained from a large volume of material that was allowed to settle under saturated conditions in a container, and subsequently, allowed to drain. The particle density was measured with the pycnometer method (Blake, 1965), using three replications.

The saturated hydraulic conductivity was found with a constant head method (Klute, 1965), and the unsaturated hydraulic conductivity as a function of water content was calculated by the method of Jackson (1972). In making these calculations an air entry value of −0.2 kPa was assumed.

The manner in which water would be retained by freely draining columns of varying heights was examined theoretically and experimentally. The water distribution after drainage was calculated with a numerical method, essentially identical to that used by Hillel and Van Bavel (1976). For the experiments, three columns of 0.15, 0.24, and 0.39 m height were made up, saturated, and allowed to drain until outflow ceased after 2 or 3 hours. Then the average water content was determined.

Results and Discussion

It was found that the dry bulk density of fritted clay was remarkably reproducible and uniform when allowing either the dry or the saturated material to settle in containers of varying size. The average value was 0.67 ± 0.02 kg/liter, resulting in a calculated total porosity of 0.73, based upon a measured value of 2.50 ± 0.01 kg/liter for the particle density.

The desorption function is given in Fig. 1. It suggests that a large amount of water can be expected to drain by gravity from the material and that it should have an adequate aeration porosity. The remaining water is rather equally distributed over the pressure potential range from −10 kPa to −1,500 kPa, though there is relatively more water present in the low-pressure portion of the range. It is also noted that relatively little water is retained in the

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tensiometer range (−10 kPa to −80 kPa). We speculate that water at pressure potentials of more than −10 kPa is held between the granules, whereas that held at less than −100 kPa is held within the granular particles.

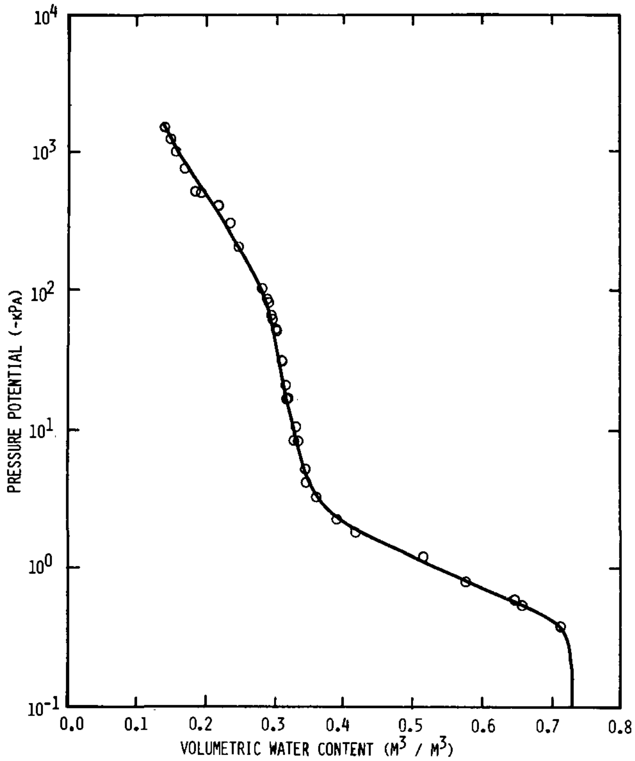

Fig. 1—Desorption curve of fritted clay.

The saturated hydraulic conductivity was found as $9.5 \times 10^{-4} \pm 0.2 \times 10^{-4}$ m/sec, or 82 m/day. This is a very high value. From it, the hydraulic conductivity as a function of the water content was calculated. The resulting curve (Fig. 2) suggests rapid drainage from saturation down to water contents of around 0.40.

Drainage calculations by numerical simulation suggested that a 0.13 m-column should be essentially drained after 10 min and a 1.13 m-column after 100 min. The calculated water content profiles after drainage are shown in Fig. 3. These results illustrate a point often overlooked by agronomists and horticulturists working with potted plants: the average water content of a container of soil or similar material after drainage decreases with increasing height. This is further demonstrated by the results obtained in the drainage experiments. The average water content of the 0.15 m-column was 0.52, that of the 0.24 m-column was 0.44, and that of the 0.39 m-column was 0.41.

We infer that in commonly used containers the water retained after drainage will be about 0.45 of the total volume, and that of this amount 0.14 will not be freely available, as it corresponds to a pressure potential of -1,500 kPa (wilting point). Thus, we can conclude that fritted clay holds plant-available water in an amount of 0.31 the volume of the container.

This is a generous quantity, and at the same time, adequate aeration is provided by an air volume of 0.28 or more of the container volume. In addition, containers filled with fritted clay weigh much less than if filled with soil or sand, and will drain readily.

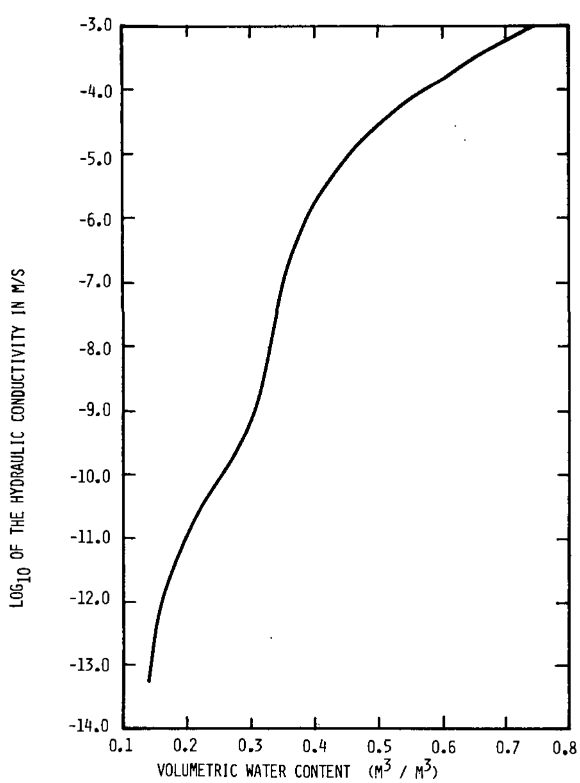

Fig. 2—Calculated hydraulic conductivity of fritted clay as a function of its water content.

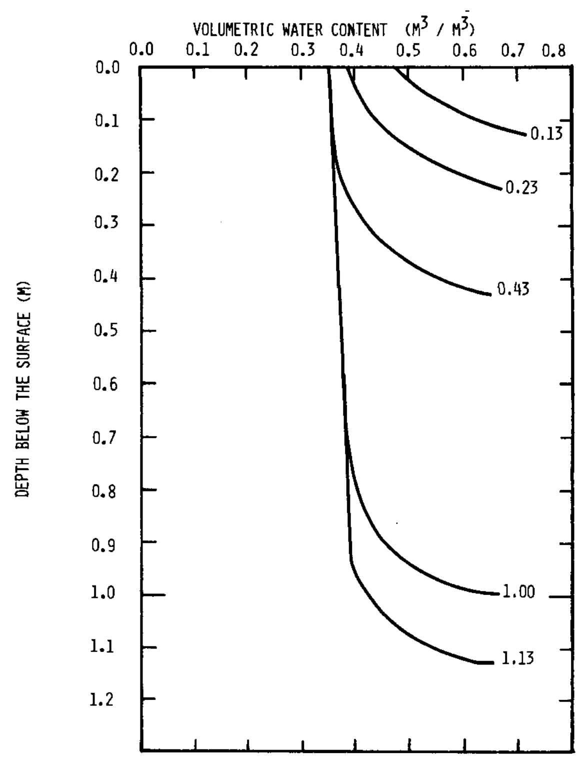

Fig. 3—Calculated water content profiles of drained columns of fritted clay of differing heights.

ACKNOWLEDGEMENT

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DETERMINING SOIL GYPSUM CONTENT AND EXPRESSING PROPERTIES OF GYPSIFEROUS SOILS[1]

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Abstract

The standard method for measuring the gypsum content of soils is a lengthy one, partly because of the presence of Na and Mg sulfates in most gypsic horizons, and partly because of the difficulty in dissolving all the gypsum in the sample. A more rapid method, sufficiently accurate for taxonomic uses, has been developed and is based on loss of crystal water of gypsum upon heating to 105° C. Percent gypsum, calculated on an oven-dry weight basis from loss of crystal water, equals 1.038 × percent gypsum by the standard chemical method + 0.17. The standard error of estimate for the new method is ± 1.8% gypsum. Equations are given for expressing properties of gypsiferous soils on an oven-dry + crystal water of gypsum weight basis.

Additional Index Words: **sulfate, soil water, air-dry to oven-dry ratio.**

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One of the standard methods for determining the gypsum content of soils is a lengthy one, partly because of the presence of Na and Mg sulfates in most gypsic horizons and partly because of the difficulty in dissolving all the gypsum in the sample. In the method soils are extracted at successively wider water/soil ratios until all sulfate is dissolved from the soil. Total SO_4 (Soil Conservation Service, 1972, method 6L1b) is measured in the extract. A correction is made for nongypsiferous SO_4 (Soil Conservation Service, 1972, method 6F1b). From this corrected SO_4, the percent gypsum in the soil, on an oven-dry weight basis, is calculated.

A more rapid method based on the crystal-water content of gypsum (20.91%) seemed a good possibility. The crystal water of gypsum is not lost when the gypsum is placed over SiO_2-gel for 48 hours in a desiccator, whereas it is lost when the gypsum is heated at 105° C for 24 hours. Air-dry samples of nongypsiferous soils and Volclay (montmorillonite) lose essentially the same amount of water when dried over SiO_2-gel for 48 hours, or heated at 105° C for 24 hours. Hence, the difference in the silica-gel dried and oven-dried sample weights of soils seemed to offer a good way to determine the content of gypsum in a soil. This note describes such a method, compares results obtained with it and with the standard method, and presents means for expressing properties of gypsiferous soils.

Materials and Methods

Soils

Gypsum was the sole $CaSO_4$ mineral in the 20 test samples as indicated by X-ray diffraction patterns.[3] Samples were from a Boralf, a Torriorthent, a Torrifluvent, and two Gypsiorthids (Soil Survey Staff, 1975) in Alaska, Nevada, Utah, and New Mexico.

Procedure

Transfer about 8 g of < 2 mm air-dry soil to a tared (wt. 1) aluminum soil moisture dish (diameter, 60 mm; depth, 15 mm) and weigh (wt. 2) to nearest 0.001 g. Repeat this procedure with about 4 g of reagent-grade gypsum or pure < 2 mm soil gypsum crystals. Add about 10 g (1 tablespoon) of dry silica gel indicating grade to an 89-ml (3 oz.) tin sample box (diameter, 54 mm; height, 35 mm). Place a circle of 3-mm (8 mesh) hardware cloth on top of the box and transfer it into a wide-mouth pint mason jar. Place the aluminum dish containing the soil on a silica gel box. Fit a sheet of plastic material over the jar and tighten the lid. Dry the soil over silica gel for 48 hours or more. Weigh the container with the soil (wt. 3) immediately. Then dry the soil in an oven at 105° C for 24 hours. If no oven is available, dry the soil for 15 min either under a 250-watt infrared lamp 10 cm from the soil or on the heating surface of a gas or electric element at 135° C. Transfer the container with the soil to the jar, fit the plastic material over the top, tighten the lid, and cool the soil to room temperature. Weigh the container with the soil (wt. 4). It is not necessary to cool the soil sample after heating at 105° C, if the sample is weighed immediately after it is removed from the oven.

Calculate the air-dry weight (AD) to oven-dry weight (OD) ratio and report it to the third place to the right of the decimal using Eq. 1.

$$\frac{\text{Air-dry wt.}}{\text{Oven-dry wt.}}\ \frac{(AD)}{(OD)}\ \text{ratio} = \frac{(\text{wt. } 2 - \text{wt. } 1)}{(\text{wt. } 4 - \text{wt. } 1)}. \qquad [1]$$

Calculate the grams of gypsum-crystal water per 1 gram of silica-gel dried gypsum and report it to the fourth place to the right of the decimal using Eq. 2.

$$Wc = \frac{\text{Crystal water content}}{\text{in gypsum, g/g}} = \frac{(\text{wt. } 3 - \text{wt. } 4)}{(\text{wt. } 3 - \text{wt. } 1)}. \qquad [2]$$

Calculate the percent gypsum by the crystal-water loss method

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[3]W. D. Nettleton, P. S. Derr, and R. E. Nelson. 1978. Occurrence and morphology of gypsum in soils. Manuscript in preparation.
[4]We thank Jose Torrent for confirming the validity of this correction.