Determination of Field Capacity in a Florida Sandy Soil and Drainage Time at Different Depths

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SUMMARY. The development of improved equipment for measuring soil water content has created the need for a better understanding of soil water drainage and movement. Without this understanding, it is impossible to know if an observed decrease in soil water content at a particular depth is due to evapotranspiration and/or continual drainage. This study was designed to determine the length of time for different soil depths of a Florida Candler fine sand to reach field capacity. A field site with no vegetation on it was saturated with water and covered with a plastic tarp to prevent evaporation. At 6- to 24-hour intervals, soil water content was measured gravimetrically in the top 15 cm (6 inches) and with the neutron probe from 30 to 150 cm (12 to 59 inches). The 15-cm depth reached field capacity after one day, but it took 4 days for the 30- to 150-cm depths to reach field capacity because of rewetting by water draining from higher horizons. The time required for drainage to stop must be considered when evaluating changes in soil water status at a particular depth. This is important for distinguishing between plant water uptake and drainage for different soil layers. Soil water characteristic curves of undisturbed soil samples, bulk

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density, porosity, and field capacity in situ were also determined for this soil. Field capacity values found in situ were compared to those found using the pressure plate technique. Laboratory values were higher than field values because the laboratory data were closer to hydrostatic conditions than the field data and the degree of saturation provided during wetting of the cores was higher in the laboratory. Water was not readily retained in Candler fine sand because the soil was very porous, infiltration rates were high, drainage was rapid, and water storage capacity was limited. Using field measurements, field capacity values of soil at different depths ranged from 4.8% to 6.2% volume for Candler fine sand. These are considered to be low values when compared to other types of soil.

Soil water status has a major effect on plant growth and productivity. Various instruments have been used to determine soil water content or tension, but many of these give only snapshot views of soil water at a particular time. Newer devices are now available which measure changes in soil water status at different depths on a near-continuous basis [e.g., capacitance probe, EnviroSCAN; Sentek Environmental Innovations, Kent Town, South Australia; and time domain reflectometry (TDR)] (Paltineanu and Starr, 1997). These devices have shown decreases in soil water over time due to plant evapotranspiration (ET) and/or drainage. Without knowledge of duration of soil drainage, it is difficult to determine if changes in soil water content are due to plant ET or drainage. This study was designed to determine field capacity in a deep Florida ridge sand and the length of time required for water to drain through the soil.

The study of water uptake and retention by soils is of significant importance. Curves showing the relation between water content and soil water tension have been intensively used to understand the physical characteristics of soils. The desorption curve, known as the soil water release curve, is commonly used (Hillel, 1980) because soil is exposed most of the time to drying conditions due to water extraction by plants. Field capacity is an important concept which is defined as the water content of an initially wetted soil after

downward movement of water has materially decreased (Hillel, 1980). Field capacity determinations in place or in situ are generally superior to those in the laboratory because it is difficult to obtain samples and transport them to the laboratory without disturbing them to some extent. Furthermore, there is no laboratory system yet devised that is capable of duplicating soil water dynamics in the field (Hillel, 1982).

Candler fine sand (hyperthermic, uncoated, Typic Quartzipsamments) is a common soil for growing citrus in the central Florida ridge. Significant differences in physical characteristics such as water holding capacities of Candler fine sands have been found among Florida counties (Carlisle et al., 1985; Hammond et al., 1967; Stewart et al., 1963). Differences within the same county have also been found, particularly in the top 10 cm (4 inches) of soil (Carlisle et al., 1985). Because small differences in field capacity in sands can make large difference in available water, a need for determining soil water characteristic curves and field capacity values for every location is important.

Florida ridge sands are particularly low in water holding capacity, and it has been stated that drainage generally ceases after 24 h (Obreza et al., 1997). However, recent improvements in soil water measurement techniques such as systems that measure the soil dielectric constants allow us to monitor soil water status at different depths almost continuously (Paltineanu and Starr, 1997). With these newer near-continuous measuring devices, it is sometimes difficult to determine if changes in soil water status are due to continual drainage, ET or a combination of both factors. Hence, it has now become more important to determine the time required for drainage to substantially decrease at different depths in sandy soils.

The objective of this study was to determine the time required for drainage within different soil depths to become negligible. Another objective was to determine soil water content values at different soil pressure heads during desorption from undisturbed soil cores, and to estimate field capacity in situ for different depths of a Candler fine sand. For extension and research personnel, it is important to understand these concepts to better evaluate drainage and plant water uptake.

Materials and methods

A neutron probe (model 503 DR; CPN Corp., Pacheco, Calif.) was calibrated in the field by the gravimetric method. The calibration was conducted by daily augering and collecting undisturbed soil samples from the depths at which neutron probe count ratio readings were taken. Volumetric soil water content values were determined after oven drying known volumes of the soil samples to a constant weight at 105 °C (221 °F). The best-fitting curve and equation relating count ratio and water content were computed. Three aluminum access tubes were installed in the soil of a citrus orchard near Davenport, Fla., for neutron probe measurements. The soil was Candler fine sand (Entisol, hyperthermic, uncoated, Typic Quartzipsamments), which was typical of the ridge area of central Florida. The site chosen was >10 m (33 ft) from citrus trees and other vegetation to avoid water absorption by roots. A large portion of soil was wetted and saturated beyond the depth of interest by irrigating overnight with one sprinkler discharging 125 L·h⁻¹ (33 gal/h). The area was then covered with a plastic tarp to prevent evaporation. Soil water content was monitored gravimetrically in the top 15 cm (6 inches) and by the neutron scattering method from 30 to 150 cm (12 to 59 inches) deep. At 6- to 24-h intervals, measurements of soil water content were taken which provided information on the dynamic pattern of internal drainage and allowed evaluation of whether any single value of soil water at any particular time could be designated as field capacity.

Water uptake and release by the soil were measured by the pressure plate technique (Richards and Fireman, 1943). Six replicate soil samples were collected at appropriate depths with a soil sampler equipped with 5.4-cm (2.1-inch)-diameter and 6.0-cm (2.4-inch)-high brass cores, which provided soil cores of substantially undisturbed structure. Samples were collected several feet apart within the neutron probe site at depths of 0 to 15, 30, 60, 90, 120, and 150 cm. The bottom surface of the soil sample was covered with cheesecloth held in place with a rubber band to retain the soil, and water was added to the top of the cylinders until the cores were nearly

Table 1. Volumetric soil water content (%) of a Candler fine sand at different soil suctions.

Depth [cm (inch)]	Suction kPa (bar)			
	10 (0.1)	20 (0.2)	30 (0.3)	100 (1.0)
0-15 (0-6)	7.52	7.06	6.48	6.17
30 (12)	6.83	6.04	5.51	4.78
60 (24)	5.78	5.07	4.55	4.13
90 (35)	5.26	4.76	4.26	3.32
120 (47)	5.52	4.90	4.49	3.44
150 (59)	6.02	5.46	5.21	3.36

Table 2. Bulk density, porosity, and field capacity of a Candler fine sand for different depths.

Depth [cm (inch)]	Bulk density ^z (g·cm ⁻³)	Porosity ^y (%)	FC ^x (%)	Time to reach FC (d)
0-15 (0-6)	1.40	47.17	6.2	1
30 (12)	1.57	40.75	5.7	4
60 (24)	1.54	41.89	5.1	4
90 (35)	1.50	43.40	4.8	4
120 (47)	1.51	43.02	4.9	4
150 (59)	1.52	42.64	5.5	4

^z1.0 g·cm⁻³ = 62.43 lb/ft³.

^yPorosity values were calculated using 2.65 g·cm⁻³ as a mean particle density.

^xFC = field capacity.

saturated. The porous ceramic pressure plate was saturated with water under vacuum. When soil samples were set on the porous plate in the extractor (or chamber) and pressure was applied, water was extracted from the soil. The water passed into a burette through a delivery tube connected to the underside of the porous plate. The equilibrium and amount of water can then be conveniently obtained without the disturbance caused by successive weighing. Precaution was taken to prevent evaporation from the burette by using a small amount of mineral oil in it. The pressures applied in the chamber were 10, 20, 30, and 100 kPa (0.1, 0.2, 0.3, and 1.0 bar). When equilibrium at the last pressure (100 kPa) was reached, soil water content was determined by drying to constant weight at 105 °C (221 °F).

Results and discussion

Soil water content decreased with increasing soil suction (Table 1). The top 0 to 15 cm of soil had the highest water-holding capacity. Water-holding capacity of the soil decreased with depth from the soil surface to a depth of 90 cm (35 inches) due mainly to a decrease in organic matter concentration. Below the 90-cm depth, water holding capacity increased with depth

due to a slight increase in clay concentration. The top 0 to 15 cm of soil had the lowest bulk density and the highest porosity (Table 2) due also to higher organic matter content and frequent tillage.

The water content of the six depths in relation to time after wetting is plotted in Figs. 1 and 2. During the first few hours after wetting, most of the water had drained at a relatively rapid rate, illustrated by the steep slopes of the soil water depletion curves (Fig. 1). One to two days after wetting, the rate of water loss due to drainage dropped to <1/10 of the initial rate, and after 4 to 5 d the rate dropped to 1/100 of the initial rate. One day after wetting, the 0- to 15-cm curve started to level off, but it took 4 d for the 150-cm curve to start flattening (Fig. 1) because of rewetting by water draining from the upper horizons. The 30-, 60-, 90-, and 120-cm curves followed the same pattern. The 30-cm curve was relatively higher than the others due to higher organic matter concentration. Field capacity at 150 cm was as high as that at 30 cm because of the relatively higher clay concentration.

Furr (1945) assumed that in sandy soils that were free of a hard-

pan, rapid drainage after wetting had to be completed in 2 to 4 d and that the water content of samples taken at the end of this period represented the approximate field capacity. Kramer (1969) suggested that drainage of gravitational water became very slow 1 to 3 d after soil had been thoroughly wetted by rain or irrigation. Veihmeyer and Hendrickson (1949) stated that field capacity was in the region where the soil water-release curve became almost horizontal. Stewart et al. (1963) arbitrarily set field capacity for sandy-textured soils at 10.1 kPa (0.10 atmosphere) tension and Schwab et al. (1966) defined field capacity in sands at 10.0 kPa tension. Recently, with the development of more precise experimental techniques in the study of un-

Fig. 1. Volumetric water content for the different depths in relation to time after wetting. **Fig. 2. Volumetric water content of the top 150 cm (59 inches) of soil in relation to time after wetting.**

saturated flow processes, the field capacity concept, as defined above, has been recognized as arbitrary and not an intrinsic physical property independent of the way it is measured (Hillel, 1982). Although the rate of water redistribution in the soil profile decreases constantly, in the absence of a water table the process continues for very long periods (Hillel, 1982).

Our field capacity values were selected based mainly on Veihmeyer and Hendrickson's criteria. These values are located on the portion of the curves corresponding to 1 day for the top 15-cm depth and 4 d for the other depths after wetting (Table 2, Fig. 1). The amount of water that was retained at 10 kPa tension for Candler fine sand was higher than the amount of water at field capacity determined under field conditions. Field capacity values determined under field conditions were close to water content values at 20 kPa suction. These data agree with Richards and Ogata's results (1956), which showed higher water retention by cores in the laboratory compared with field determination. This was attributed to the higher degree of saturation provided during wetting of cores in the laboratory. From a practical standpoint, bringing water content above field capacity by irrigation would be inefficient because this water will be lost by percolation and/or deep drainage. Nevertheless, because of the small amount of water held by this soil, it is also important to prevent the water content from falling low enough for plant water stress to occur.

Conclusions

Candler fine sand holds a relatively small amount of water and drains easily. Although the top 15 cm reaches field capacity in ≈ 1 d, it takes 4 d for depths to 150 cm to materially stop draining. When monitoring plant water uptake from different soil depths, it is important to know how those particular depths will continue to lose water by drainage.

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