Golf Course Drainage

First of a series of articles written exclusively for The National Greenkeeper by America's foremost golf course drainage engineer

THE need for under-drainage and aeration of golf course soils is universal. If the natural character of the soil does not permit of rapid percolation of rain or irrigation water and the retention of sufficient moisture for luxuriant growth, artificial means must be used to change the soil conditions.

Nearly all the processes of plant food liberation within the soil and the absorption of these foods by grass plants are dependent upon the proper balance between moisture and air in the soil.

In approaching a study of land drainage one must have a clearly defined idea of the functions of water in the soil. This first article is therefore confined to this subject, soil moisture, for the reason that it explains the reason for tile drainage.

Editor's note: Mr. Miller was formerly Extension specialist in Agricultural Engineering at Ohio State University, and his background of training includes several years of study in soil physics and chemistry. Since 1920 his unusual abilities have been devoted to solving the drainage and soil improvement problems on golf courses.

In later articles dealing with the mechanics of tile drainage numerous points will be raised which are open to individual opinion, but the statements made here in regard to soil moisture admit of very little dispute. However, you may have at this time a very different idea of the subject and its value in golf course management.

Source of Soil Moisture:—Of the water which falls to the earth's surface as rainfall, or is applied in irrigating, one portion runs away over the surface to the natural surface drainage channels, another portion seeps into the ground, and the third portion evaporates from the place where it falls. It is this second portion, that which is taken up by the soil, which is of particular interest in this discussion.

Moisture Content of Soils:—The capacities of soils to take up and hold moisture vary greatly with the different soil types and formations. The soils with the larger percentages of porosity hold the larger amounts of moisture. The moisture content is usually expressed as a percentage of either the dry weight or of the volume expressing it as a percentage of the volume. Table I shows how widely the moisture capacity of soils vary with the fineness of the soil grains. The maximum and minimum moisture content each increases as the size of the soil grains decreases. Any treatment, such as under-drainage, that will tend to increase the moisture capacity of a soil without too great injury in some other respect is desirable.

Moisture Content and Turf Production:—The amount of moisture necessary for good turf production varies greatly with the soil texture and structure, the turf and the climate. Lyon and Fippin state in their text, "The Principles of Soil Management," that "—other things being equal, more water will be required in an arid region than in one of humid climate; more in a warm region than in a cold region; more in a clay soil than in a sandy soil; more in a windy section than in a region of still atmosphere; more with a high soil-moisture content; more on a poor soil; and lastly, more water is used per pound of dry matter produced in a small growth of turf than in a large growth. Not only is the total seasonal requirement to be considered, but the maximum demand of the turf at any period of its growth must be met."

Forms of Soil Moisture:—Soil moisture is of three different classes: (1) Gravitational water, or that water which is free to move in the soil under the influence of gravity; (2) Capillary or film moisture, which is held, by surface tension against the influence of gravity; and (3) Hygroscopic moisture or that which condenses from the atmosphere upon the surface of the soil particles.

Gravitational Moisture:—Land drainage has been aptly defined as the removal of the surplus moisture from the soil. (*Usually this is only the means to an end, as the benefits of drainage are due to those actions made possible by the removal of the surplus moisture.*) Under-drainage is the removal of this water by artificial or natural means under the surface. As it is only the *gravitational soil water* which is free to move under the in-

TABLE I

MOISTURE CAPACITY OF SOILS

	Water Capacity Min. %	Water Capacity Max. %	Amount of Available Water %	Amount of Available Water Cu. In. per Cu. Ft.	Amount of Available Water Depth Inches in top 4 ft. of soil
Light Sandy Loam-Early Truck Soil	3	8	5	122	3.4
Silt Loam-Bluegrass Soil	15	25	10	218	6.0
Clay-Black Cretaceous Prairie Soil	23	40*	17	274	7.6

(From "The Principles of Soil Management", Lyon & Fippin).

*Assumed.

fluence of gravity, and which is *unavailable* for and *injurious* to plant growth, the need for drainage is proportional to the amount of this form of moisture present in the soil.

When the supply of soil moisture is replenished by rainfall that part in excess of what can be held on the soil grains by capillary attraction becomes gravitational moisture. As the water percolates from the surface downward the thickness of the films of capillary moisture on the undivided soil grains near the plane of saturation is gradually increased until after the full capillary moisture capacity has been supplied. This of course takes no account of the relatively large amount of water which passes from the saturated surface through the shrinkage cracks, small root cavities and worm bores downward to the zone of permanent saturation.

Gravitational Moisture Content of Soils:—The gravitational water-content is directly proportional to size of the spaces and is also the difference between the total moisture content of a given soil and the capillary and hygroscopic moisture contents. If the pore spaces become too small they may be almost entirely filled by capillary moisture as is the case in the fine grained clay soils. In general it may be said that the gravitational water capacity decreases as the total amount of pore space increases, because the largest total percentage of pore space is ordinarily found in the soil having the smallest grains and the smallest individual pore spaces.

Only a very small part of the gravitational moisture in the soil is available for plant use, and the major portion of it is injurious to vegetable life. Below the plane of saturation it completely fills the pore spaces in the soil, thus excluding the air. Most authorities on soils and turf culture contend that aeration, or the passage of air through the soil is one of the most important factors of grass production. The function of air in the process of plant food manufacture within the soil is a subject needing a separate and full discussion.

Water Table:—The surface of the gravitational water in the soil, or the surface of the saturated layer, is commonly called the water table. It is also referred to as the groundwater level, groundwater in this sense meaning gravitational soil moisture, or surplus moisture.

It sometimes happens that the presence of air in the soil causes two planes of saturation. After a rain there is sometimes a saturated surface layer and a true groundwater level at a greater depth. The pore spaces of the intermediate layer of soil are filled with air which excludes the water till such a time as the air can pass out through the upper saturated layer.

Between periods of rainfall the movement of capillary soil moisture is from the water table upward. In this one particular, that of furnishing a source of supply for capillary moisture, the gravitational moisture is very beneficial.

Capillary Moisture:—In so far as plant life is concerned, capillary water is the most valuable form of soil moisture and, in fact, the only form of water which is available for the sustaining of plant growth. Capillary water is held, against the force of gravity, in the small pore spaces between the soil grains and as a thin film surrounding each individual particle or group of soil particles. Every one has noticed the rise of water in a small bore glass tube when the lower end is immersed in water, the height to which the water rises increasing as the size of the opening in the tube decreases. It is the same force, surface tension, which holds the capillary water in the soil.

Capillary-Moisture Content:—In the field the grains of soil are surrounded by connecting thin films of moisture and the finer the soil particles the greater the surface area which holds this film of moisture. This variation of the capillary moisture capacity of soils with different sized grains is illustrated by the data in Table II.

TABLE II
MOISTURE CONTENT OF SOILS

Kind of Soil	Weight Per Cu. Ft. Pounds	Pore Space %	Maximum Water Cap. %	Maximum Capillary Cap. %	Max. Gravitational Cap. %	Max. Gravitational Cap. Depth Inches in Top 4 ft.
Dune Sand	80	52	40.5	10.7	29.8	18.3
Coarse Sand	81	51	39.5	10.6	28.9	18.0
Fine Sandy Loam	83	50	38.0	18.0	20.0	12.7
Silt Loam	83	50	38.0	20.9	18.9	12.1
Clay	68	59	54.5	30.4	13.9	7.3
Muck Soil	15	80	333.0	250.0	83.0	9.6

(Note.—Percentages are figured by weights. (From "Principles of Soil Management," Lyon & Fippin).

An idea of the amount of water held in soil by the films of capillary water, and the thickness of the film, may be obtained by considering the fine clay soil where the effective diameter of soil grains is 0.005 m.m. or less. Professor King has determined that for 1 cubic foot of such soil the area of the surface of the soil grains is 173,700 sq. ft. or approximately four acres. Water equivalent to four inches in depth over one square foot could be held in one cubic foot of this soil if the thickness of the film was 4/173,000 inches, or about one-half the thickness of a soap bubble just before it expands to the bursting point.

Available Capillary Moisture:—However, not all of even the capillary moisture is available for plant use. A cer-

TABLE III
AVAILABLE MOISTURE IN SOILS

Kind of Soil	Dry Porosity %	Approximate Per Cent of Water Crops Will Wilt	Available Moisture Water Still Held in the Soil When Grass Will Wilt %	Depth inches in top 4 ft.
Dune Sand	52.2	3.0	7.7	4.6
Coarse Sand	51	3.0	7.6	5.2
Fine Sandy Loam	50	5.0	13.0	8.5
Silt Loam	50	10.0	10.9	6.9
Clay	59	17.0	13.4	7.0
Muck Soil	*80	80.0	170.0	20.5

*Assumed

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tain portion of it is held so intimately that the small roots cannot draw it from the soil.

Capillary Moisture and Drainage:—Capillary moisture has no direct relation to underdrainage though it has a very definite and important bearing upon the results and effects of drainage. When the plane of saturation is lowered by the use of underdrains the moisture necessary for grass production must be supplied by capillarity.

Hygroscopic Moisture:—This is the least important of the three forms of soil moisture and in amount it is relatively very small. It is the moisture which condenses from the air onto the soil grains, the condensation taking place either at the surface or in the soil, if it be so open as to allow of free circulation of air.

(Each of the articles by Mr. Miller which will appear in following issues will specialize on a phase of soil drainage, including a discussion on the benefits of drainage, determining where drainage is needed, the design of tile drainage systems, the mechanics of drainage installation, and the construction of drainage accessories.)

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