(3) Be absorbed by the soil and lost by evaporation from the surface of the soil or through cracks which develop.

(4) Be absorbed by the soil and used by the plant.

Obviously, if the moisture supply is deficient, we wish to avoid the first three types of losses and retain as much as possible for the plant. Steep slopes and hard surfaces increase runoff, whereas gentle topography and porous soils reduce it. Percolation may be reduced by increasing the water-holding capacity of the soil, but on many courses there are greens, portions of fairways, and tees, where there is too little percolation for healthy growth.

Evaporation may be partially controlled by improving soil structure to avoid cracks in the soil, and by top dressing with soils having a desirable texture and organic matter content. From 2 to 3 times as much water is evaporated from sandy soils as from loams, whereas clayey soils which bake and crack also lose moisture more rapidly than loams. However, evaporation is largely controlled by weather conditions and we have not yet found suitable methods of reducing evaporation losses in hot, dry periods.

The quantity of water retained by the soil for use by the plant depends on soil texture, structure, and organic matter content. Table 3 shows the *available* moisture capacities of three soil types. The rich silt loam is able to hold more than twice as much water in an available form, as the sandy soil. An important point in this connection however, is the amount which the plant may draw on. Obviously if the root system is restricted to the upper inch of soil because of unfavorable soil conditions, or wrong methods of treatment, the plant may use only the moisture present in that inch layer. If the root system penetrates 2 inches, the potential supply is doubled, and for 4 inches it is four times as great. It is evident that much can be done in the way of increasing the moisture supply for all types of turf, merely by making conditions suitable for vigorous development of the root system.

Golf courses are frequently built on soils that require much treatment to make them suitable for growing turf. One of the most frequent soil defects which is encountered is the lack of sufficient organic matter. In clayey soils, this causes a compact structure with excessive runoff, baking and cracking in hot dry weather, accompanied by great

Table 3. — Available Water Held by Soils for Plant Use — Gallons per 1000 Square Feet*

Kind of Soil	*Depth of Soil in Inches* 1	2	3	4	5
Sandy soil	99 gal.	198 gal.	297 gal.	396 gal.	495 gal.
Average silt loam	140 gal.	280 gal.	420 gal.	560 gal.	700 gal.
Rich silt loam	208 gal.	416 gal.	624 gal.	832 gal.	1040 gal.

**One inch water on 1000 square feet=623 gallons.*

(For field conditions. Calculated from data given by Lyon & Buckman, "The Nature and Properties of Soils")

losses of moisture by evaporation, and poor structure which reduces the water-holding capacity as well as aeration. With sandy soils, the lack of sufficient organic matter permits rapid percolation of moisture through the soil thus carrying off the soluble nutrients which the plant needs, and insufficient moisture is retained for plant absorption. Loam soils are not so urgently in need of organic matter as clayey and sandy soils, but they are greatly improved by its presence in liberal quantities.

We have conducted experiments at New Jersey on the value of different types of organic matter for improving the physical condition of soil. Certain of the results obtained are given in Table 4. The detailed discussion of these experiments will soon be published elsewhere, but the data given here shows clearly that the available water-holding capacity may be changed considerably by the incorporation of the right type of organic matter.

The real value of the various types of organic matter must not be judged by these data alone, since such factors as the texture of the materials, the ease with which they take up moisture, their persistence in the soil, the effect on evaporation losses, etc., must be considered. The important information contained in these figures is that grass growth was increased over 50 per cent on the sand, and at least 15 per cent on the clay by the incorporation of organic matter in quantities equivalent to about 30 tons of manure per acre.

ABSORPTION OF MOISTURE

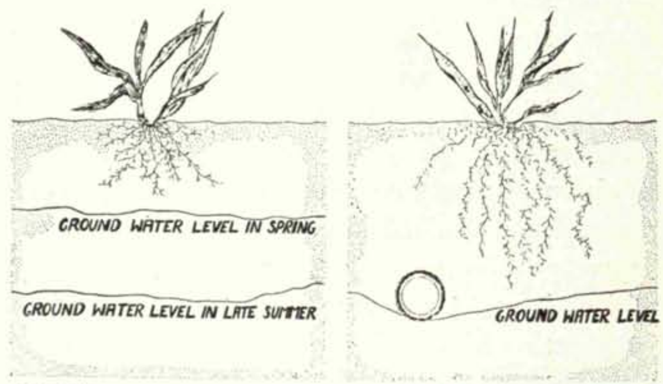
WHATEVER the structure and moisture-holding capacity of the soil, the plant will not use such water unless the soil is occupied by the root system. Roots of turf grasses are stimulated by some conditions and inhibited in growth by others. Poor soil drainage always means scanty root development. This is largely due to the exclusion of oxygen from the pore spaces by the presence of too much water. Figure No. 3 shows the relation between drainage of a wet soil and root development. In some soils, poor drainage is caused by the presence of a compact layer of clay or shale which presents removal of superfluous water by percolation. In others, the soil itself is naturally so compact that excess moisture

Table 4. — The Effect of Adding Organic Matter to Soil, on Water Holding Capacity and Growth of Grass

Type of Organic Matter Mixed with the Soil	*Sandy Soil*		*Clay Loam Soil*	
	Available Water Holding Capacity	*Yield of Grass*	*Available Water Holding Capacity*	*Yield of Grass*
	%	*gms.*	%	*gms.*
Cultivated New Jersey Peat	19.6	9.8	29.0	11.0
Raw Michigan Peat	20.2	8.9	31.8	11.1
Imported Peat Moss	27.6	10.0	34.1	10.8
Spent Mushroom Soil	17.8	9.5	27.6	11.6
Well-Rotted Manure	18.3	10.4	31.3	11.6
Untreated Soil	16.1	6.2	26.0	9.6

is not eliminated normally. However, in many cases, poor drainage is the result of continuous over-watering which compacts the soil. The roots of turf plants find difficulty in occupying such soil and therefore may penetrate only the upper layers. This unhealthy condition often passes unnoticed until a period of hot dry weather occurs, when the turf suddenly fails because of inability to satisfy its moisture requirements by absorption from the thin surface layer of soil.

Paradoxical as it may seem, over-watering may easily result in injury from moisture deficiency. On the other hand, the soil must contain a certain supply of water or roots will not grow and function. A system of watering which provides for wetting of only the upper inch or two of soil, will force the plants to confine their root systems to this moist layer. A sudden heavy watering to a



GROUND WATER LEVEL AND EXTENT OF THE ROOT ZONE

greater depth will have little benefit, since the plant can draw only on the soil zones occupied by the root system.

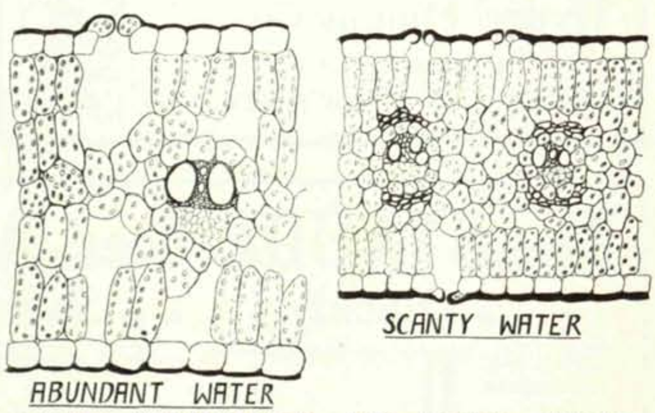
Another factor which greatly influences water absorption is the acidity of the soil. Certain grasses such as the bents, are more tolerant of acidity than others, such as Kentucky blue grass. Nevertheless, it is a well known fact that strong acidity will prevent the formation of root hairs and thus reduce the absorption of moisture. Moreover, even with contact of roots and water, it has been shown that absorption is much slower with strong soil acidity than with mild acidity or neutrality. We have found striking support of this fact in our tests with creeping bent turf in New Jersey. Where the soil has become acid through continued use of sulphate of ammonia, Ammo-Phos, and similar fertilizers, the turf suffered a great more from lack of moisture during the dry season of 1930, than on other plots receiving the same care but having lower degrees of acidity.

The system of fertilization that is followed greatly influences root development and the absorption of water from the soil. Phosphate fertilizers have in general been found to increase the extent of the root system if this element is deficient in the soil. A very large percentage of soils in the eastern half of the United States are known to be lacking in phosphorous, which means that attention must be given to correcting this deficiency by proper fertilization.

Quite contrary to the effect produced by phosphates, nitrogen in abundant quantities is known to reduce root development. This is particularly true when the element is supplied in the form of soluble fertilizers such as sulphate of ammonia, nitrate of soda, and Urea. Physiologists have discovered that when the supply of nitrogen absorbed is great in proportion to the food made in the leaves, the development of roots is retarded. On the other hand, if the supply of nitrogen is relatively small as compared with food reserves, root development is stimulated. It is clear therefore, that nitrogen must be supplied in small quantities but in a regular manner, if normal development of the plant is to take place.

Nitrogen is less likely to be applied in excess if it is in the organic form, such as tankage, cottonseed meal, castor pomace, and similar materials. These substances must decompose before the nitrogen is released for plant use, and the quantity available at any one time is usually not great enough to destroy the physiological balance within the plant. It is very important that soluble nitrogenous fertilizers be applied in small quantities. Even though burning may be avoided, large amounts will stimulate a rank growth of juicy tender stems and leaves without a corresponding root development.

In addition, it may be well to remember that poisonous materials such as copper, will kill roots even though the copper be combined with other substances, as in Bordeaux spray. A thin layer of



LEAF STRUCTURE AND WATER SUPPLY

poisoned soil prevents roots from developing in this zone, and also eliminates the possibility of utilizing the moisture or nutrients in soil below this layer. Some poisons such as copper are stationary in the soil, but other such as chlorates may be washed out.

QUANTITIES OF WATER REQUIRED

THE water requirements of turf grass are not great in themselves. In moisture loss by runoff, percolation, and evaporation could be avoided, and the rainfall stored for use by the plant as required, there would be little need for artificial watering. There are no accurate figures available on water requirements of turf grasses, but the approximate quantities of water used by grasses cut at fairway length have been calculated and are given in table 5. The amount of water required day by day varies

Table 5. — Calculated *Daily* Water Requirement for Grass per 1000 Square Feet

	For Season April-October	For July Only
Massachusetts		
Fertilized grass	11.0 gal.	22.0 gal.
Unfertilized grass	8.4 gal.	16.8 gal.
New York and Vermont		
Average grass	16.0 gal.	32.0 gal.

Based on water requirements of Shantz & Piemeisel, Jour. Agr. Res. V. 34. 1927.

Grass yields from pasture experiments, Cornell Bul. 424, Vermont Bul. 295, and Jour. Amer. Soc. Agron. V. 21, 686-699. 1929 (for Mass.)

with the weather. It is likely that the quantity required on certain days in extremely hot, dry weather might even be double the average for July. However, if an average of 45 gallons of water were required daily to prevent wilting of the plants, a sandy soil should contain enough moisture in the surface inch to meet this need for two days.

Actually, the loss by evaporation on a sandy soil is probably as great as that of transpiration. Unless the roots have occupied layers of soil to a depth of 3 or 4 inches, daily artificial watering is a necessity on such soils, no matter whether the turf is on greens, tees or fairways. The moisture situation is not so critical on loamy soils because of their greater water-holding capacities, but considerable water is lost by runoff, percolation, and evaporation, and if root systems do not occupy more than the upper inch or two, severe injury may be expected in droughty periods.

The height of cut greatly influences the development of the root system. All of the plant's food is made from water, minerals, and carbon dioxide gas in the leaves of the plant. Close cutting removes a part of the leaves, and the closer the mowing the smaller is the leaf area remaining for the manufacture of food. New roots may be made only with food manufactured in the leaves, and the net result of close mowing is therefore shallow root development.

If close mowing is accompanied by heavy nitrogen fertilization, root development is still further reduced, making the grass very susceptible to drought injury as well as other ailments. Close mowing on greens is unavoidable, but there is little need for mowing fairways closer than three-quarters of an inch. The drought injury suffered in 1930 by many golf courses was probably greatly increased by the practice of mowing closely, a custom which has become prevalent in recent years.

MOISTURE SUPPLY AND QUALITY OF TURF

THE greenkeeper is not so concerned with the *quantity* of grass produced as the *quality*. The supply of water has much effect on quality. When a watering system has been established making it easy to supplement natural rainfall by irrigation, the tendency is to use more water than is desirable. The ill effects of continued overwatering on soil conditions has been discussed, but the direct effect on the grass itself is perhaps still more important. The grass leaves are modified in both size, and ability to endure harsh treatment, by the quantity of water supplied during the development, as shown in Figure 4.

In general we may say that the smaller the supply of water during leaf growth, the smaller will be the individual leaves, but the greater will be the thickness of the cell walls, the greater the development of strengthening tissue and the lower will be the content of moisture. Grass developed with a relatively small supply of water will therefore be much better able to withstand the wear given turf on golf courses than that given an abundant supply. It is true that growth is slower with less moisture, but on the other hand the grass produced under such conditions will suffer far less when droughty periods occur, and will also be less susceptible to disease.

In watering one should always moisten the soil to a depth as great as that desired for the root system. Periodic moistening to a depth of 4 or 5 inches is far more desirable than daily sprinkling which penetrates only 1 or 2 inches. [Editor's Note: Jno. Morley has said this for years.]

The ideal system of watering for the golf course should be one in which only enough moisture is provided for rather slow but hardy growth. Wilting should be avoided when possible, but it is better to run the risk of occasional wilting than to supply excessive moisture and produce soft, tender turf susceptible to injuries of many kinds.

The Bookkeeper and the Greenkeeper

By EDWARD W. DOTY, *Treasurer*
The Cleveland District Golf Association

Read at the 5th Annual Educational Conference of the National Association of Greenkeepers of America, held at Columbus, Ohio, February 3-6

MAINTAINING the golf course is the job of the greenkeeper. Writing the history of the cost of that maintenance is the job of the bookkeeper.

The interest that the greenkeeper has in the bookkeeper's job centers entirely in the result of the writing of that history. The result of the work of the bookkeeper in this particular depends upon the knowledge, the experience, and the desire of this bookkeeper.

The one who keeps the books showing the history of the maintenance of a given golf course, should not only have knowledge of accounting but also somewhat of greenkeeping. Such a one should have experience as a golf player as well as an accountant.

He ought to want to show the final results as to costs of maintenance so that the efforts of the greenkeeper be they good or bad, shall be unconfused with any other operation of the organization.

There are so many things bought for a country club, and used in its various departments, that some knowledge of greenkeeping on the part of the bookkeeper is essential for the proper inclusion and exclusion of charges sought to be assigned to greenkeeping.

I have in mind a very competent bookkeeper; so competent was he that he had invented many forms for quick and certain bookkeeping methods. He knew all about debits and credits and he could show you in half a minute just what the balance, if any, was in any fund or the sum total that he had charged up against the various activities of the organization.

The trouble with his accounts was not that they were inaccurate, or that they would not balance, but that the figures which he gave as the cost of maintaining the course could not be depended upon because of his own ignorance of what ought to be included. He was not a golf player but just a bookkeeper who knew what debit and credit meant but not whether the cost of trophies should be charged to the golf course or to something else. The result was utter confusion when attempting to use the result of his year's efforts.

Bookkeeping can be just as intricate as one wants to make it; but I have noticed that the more intricate it is, the less the greenkeeper can know about the accounts.

GREENKEEPERS INTERESTED IN BOOKKEEPING

OF course greenkeepers are not at all interested in the general bookkeeping scheme of their clubs. What they want to know is exactly what it costs to keep their own courses in proper shape for their members to play golf upon any time they desire. They are interested that only those things that are necessary to that end are included.

They are not interested in charges for depreciation nor any allocation for general expenses, nor anything else for which they are not entirely responsible. Depreciation charges are proper enough in a club's bookkeeping scheme but that is no reason for carrying them into the public exhibit of maintenance costs.

By confining maintenance costs to those "out of pocket costs," all of which the greenkeeper is directly responsible for, relegating whatever other entries that may be necessary to the general bookkeeping plan, simplifies the task and makes comparisons with other efforts along the same line easy and therefore more certain and altogether more illuminating.

My own plan starts with a definition. I attempt to set forth exactly what the task of the greenkeeper is.

I define the maintenance of a golf course as the work necessary to keep a given course in proper condition to play the game of golf according to the rules of the U. S. G. A.

That sounds simple enough and one would naturally think that nothing else could be done by anybody, and yet I will venture to say that the bookkeepers of a large number of country clubs mix into the costs of maintenance, accounts of many things that ought not to be there and with which the greenkeeper has nothing to do. These costs will run from $100 to $300 per hole per year.

In other words a greenkeeper with these extra costs loaded into his figures will find his costs per hole set down as that much more than they should be. When his efforts thus set forth are compared with the results of the work of a greenkeeper whose accounts do not include these costs, such a comparison means nothing.

For instance there is the printing of score cards. Score cards are not necessary for the playing of golf. Score cards are not ordered or their use controlled by the greenkeeper. Their cost should not be included in the cost of course maintenance. The cost of a caddymaster, of a golf professional, of trophies, of ice and towels at the tees,—all of these are desired by members and most clubs have them, but in no standardized fashion; and whether they are standardized or not, they have nothing to do with maintaining the course—the job that the greenkeeper is charged with.

SET UP FOR COURSE MAINTENANCE

IN my own accounts and in such statistical work as I have attempted in the Cleveland district, have used the following set-up for course maintenance:

Auto license, cement, cinders, electric light and power, equipment, new; equipment, replaced; express and freight, fertilizer and seed, flags, gasoline and oil, green section dues, hardware, lumber, miscellaneous, motor and machine repairs, paint, payroll, postage, printing and stationery, sand, teaming, telephone and telegram, tile, top soil.

There might easily be some slight modification of this list; I have made some changes from time to time. Once we had a line for barn costs and for horseshoeing; now we don't. But the list as given above is what I am using now. If anything should arise that includes any proper cost for course maintenance, I would add that item.

In this list there is no item that we do not use sometime during the year. When we get through and add up the figures we have what it has cost our club to maintain our course so that golf may be played upon it at any time during the season according to the rules of the game.

GREEN SERVICE COSTS

THIS leaves quite a list of things that cost the club money, which seem to have more or less to do with the play of golf. These services and goods I group together under the title of "green service." Green service therefore includes all accounts of costs of goods and services that are desired by the members for the play of golf, but which are not absolutely necessary therefor. In my accounts the items under green service are as follows:

Association dues, ball washers, caddy house repairs, electric light and power, ice, laundry, miscellaneous, payroll, postage, printing and stationery, repairs, trophies.

In the case of the clubs that I have to do with, and especially my own club, the inclusion of green service costs in the cost of maintenance would increase maintenance cost from $250 to $350 per hole.

The interest of the greenkeeper in this matter is very acute. If he is to be judged by the history of his work as set forth in figures, that history should include only that for which he is responsible. Any