Some Water Relations of Turf Plants

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WATER is one of the most important substances connected with life in this world of ours. The plant uses water in some form at every stage in its life period. Germination cannot proceed without moisture, and the first organs produced by the growing plant are roots for the absorption of water.

Water makes up 50 to 90 per cent of the growing grass plant on fairways, tees, and greens. Even such structural parts of the plant as cell walls, vessels for translocation of food materials, fibers, and tissues for mechanical support, etc., are produced in the plant by combining water with other substances. Approximately 35 to 55 pounds of water is required for every 100 pounds of such tissues formed.

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The material which plants use as food, principally the starches and sugars, require 55 to 60 pounds of water for every 100 pounds of food manufactured. The plant's food is actually made in the leaves of the plant, but this process can only take place when the cells and cell walls are kept moist with water. The nitrogen and minerals which the plant must obtain from the soil, and which is frequently added in the form of fertilizer, only enters the roots when dissolved in water. These minerals are transported to the various parts of the plant in a stream of water which extends from the roots, through the stems, to the very surface of the leaves.

The food manufactured in the leaves is carried throughout the plant wherever needed, but only as it is dissolved in water. The combination of sugars, starches and other substances with the nitrogen and minerals to form protoplasm and cell walls for new cells, in roots, leaves and stems, takes place only with an abundant supply of water.

When the plant finally dies, it is decomposed by bacteria and molds which also require moisture for their activities. In nature, the decaying plant is broken down to its elemental components, which are water, carbon dioxide gas, and minerals. At an intermediate stage in this process of decay, humus is produced. When added to the soil, this decayed organic matter greatly modifies its water holding capacity, and other physical properties.

SEASONAL SUPPLY OF WATER

SINCE water plays such a vital part in the life of plants, it is extremely necessary that we consider the problem of providing sufficient moisture for normal growth. We have two principal sources of water on golf courses; one is natural rainfall, and the second is irrigation by some one of several systems. The goal that greenkeepers and others interested in turf management should bear in mind is that natural rainfall must be supplemented by irrigation, *only* to the extent necessary for moderate growth, and never in excess. The critical season of moisture deficiency in the northeastern states usually comes in June, July, and August, because of the relatively low efficiency of the moisture which is applied in this period.

The rate at which water is lost to the air by evaporation largely determines the efficiency of rainfall. The comparative figures for rainfall and evaporation for the 5-year period from 1924-1928, inclusive, are given in Table 1 for 5 locations in the eastern United States. Whenever evaporation is greater than rainfall, artificial watering is required on greens. If evaporation is 1½ to 3 times as great

Table 1. — Comparison of Rainfall and Evaporation from a Free-Water Surface at 5 Stations Averages for the Years 1924-1928, Inclusive

Station		*April* (in.)	*May* (in.)	*June* (in.)	*July* (in.)	*Aug.* (in.)	*Sept.* (in.)	*Oct.* (in.)
Columbus, Ohio	Rainfall	3.07	3.52	4.27	4.74	2.49	2.99	2.33
	Evaporation	3.23	4.37	5.14	5.53	4.70	3.42	1.95
Ithaca, New York	Rainfall	3.09	2.82	3.46	3.86	2.92	3.51	3.18
	Evaporation	3.24	3.41	4.66	4.92	3.80	2.53	1.46
New Brunswick, New Jersey	Rainfall	3.53	3.35	3.58	5.47	6.55	4.47	4.63
	Evaporation	3.84	4.89	5.39	5.48	4.52	3.64	2.72
Chapel Hill, North Carolina	Rainfall	3.99	2.70	5.10	5.44	6.22	7.38	2.55
	Evaporation	4.12	5.05	5.56	5.83	5.16	4.19	2.79
Wichita, Kansas	Rainfall	4.29	2.66	5.35	3.01	2.84	3.22	2.97
	Evaporation	6.22	7.56	9.26	9.42	8.85	6.67	4.25

as rainfall, watering of closely-cut fairways also will be necessary, particularly if the soil has a low water holding capacity.

THE GERMINATION PERIOD

THE most critical phases in the life of a grass plant are the period of germination, and the stage of growth immediately following, when the young plant is becoming established. Water must be provided before the process of germination can begin. A continuous supply must be maintained after the young shoot emerges or death will result. Grass seed is planted very shallow because of its small size, and the difficulty of maintaining a suitable moisture content is therefore great. A few hours of drying weather may remove enough water from the surface soil to destroy a stand of seedlings which has taken weeks to establish.

Certain grasses require a longer period for germination than others, and the moisture content of the surface layers of soil must be maintained until the plant has developed a good-sized root system. The germination period for 10 of our turf grasses is given in Table 2. It is evident that the grasses which are most useful for turf on golf courses require 2 to 4 weeks for germination, with temperatures of 70 degrees F. or above. When the temperature is lower than 70 degrees more time is required. The period of establishment follows germination, and moisture is even more necessary for this phase than for germination. Sprouting seeds may undergo drying for short periods without great harm, whereas after the first leaf emerges even a severe wilting may prove fatal.

The common practice among successful greenkeepers is seeding at the season of the year when the least difficulty is experienced in keeping the surface soil moist. It is apparent from Table 1, that late summer and early fall are the most favorable periods in many regions. The chief concern with such seeding dates is to allow at least two months of growing weather before the temperature of the soil approaches the freezing point.

One month of this period is required for germination, and the other for establishment of the young plants. If grass seed is planted through necessity at other seasons of the year, constant care is required to insure the maintenance of a satis-

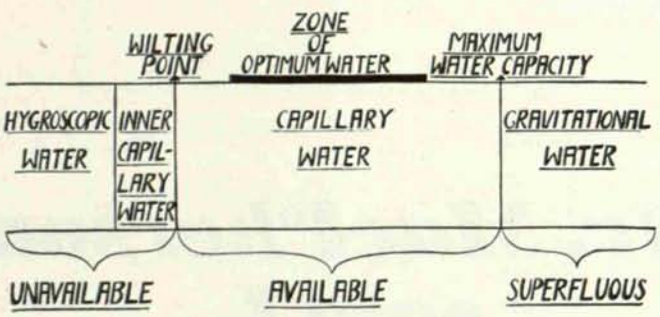
Table 2. — Conditions for Germination of Grass Seeds

Kind of Grass	*Optimum Temperature Degrees F.*	*Germination Period at Optimum Temperature* *Majority Seed Days*	*All Seed Days*
Kentucky blue grass	70-85	14	28
Canada blue grass	70-85	14	28
Redtop	70-85	5	10
Bent grass	70-85	10	21
Red fescue	70-85	10	21
Fine-leafed fescue	70-85	10	21
Meadow fescue	70-85	5	10
Rye grass	70-85	6	10
Bermuda grass	70-95	10	21
Carpet grass	70-95	10	21

The germination period is considerably extended when temperatu below those indicated.

(From U. S. D. A. Department Circular 406, Rules for Seed Testing

FORMS OF WATER PRESENT IN THE SOIL AND THEIR RELATION TO TURF PLANTS



factory moisture content. Water must be applied daily and perhaps more frequently during dry periods, and in such a manner as to avoid the formation of a crust at the surface. New seedings may be made at any time during the growing season, if attention is given to the watering. However, the most satisfactory period is one in which evaporation is no greater than rainfall.

SOIL MOISTURE

During the germination stage, water is absorbed through the walls or coverings of the seed. As soon as growth begins, a root system is developed, and practically all of the moisture required by the plant is taken in by the root system from that time on. Since the plant draws its water from the soil, it becomes necessary to consider the forms in which water is present and the use which the plant makes of each.

For convenience we divide the moisture which may be present in the soil into three parts, in the manner shown by figure 1. One part is so closely held by the soil particles that the plant can make no use of it; this is termed *unavailable water*. The second form of water is that retained in the soil by capillary attraction, and most of this is *available* to plants. The third form, known as gravitational water, is that present immediately after a heavy rain or watering. Gravitational water drains off in a short time, and the plant utilizes little of it. Such *superfluous* water is undesirable since it occupies pore spaces in the soil which should be filled with air. The *maximum water holding capacity* is the amount of water which a soil contains after the superfluous water has drained off.

We may compare the water relations of various soils by calculating their capacity for holding moisture in an available form. For example, a certain sandy soil may have a maximum water capacity of 17 pounds per 100 pounds of soil. However, in this soil about 4.5 pounds of water will be unavailable, leaving a potential supply of 12.5 pounds for use by the plant. For a loamy soil, the supply of available water will probably average 25 to 30 pounds for each 100 pounds of soil, more than double that of a light sandy soil.

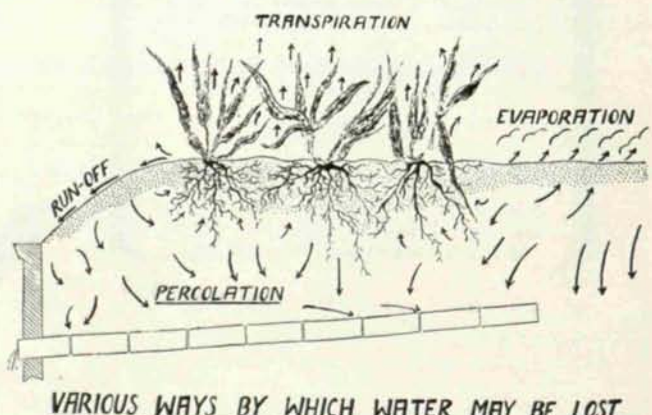
Fortunately the water content of soil may vary considerably and still permit plants to grow normally. As shown in figure 1, the optimum moisture content lies between the point of maximum capacity and the point at which no more moisture is available. We term this the optimum moisture content because the plant is able to absorb sufficient moisture to prevent wilting, and there is enough air left in the pore spaces of the soil for healthy root growth and activity. At the optimum moisture content, the desirable bacteria and molds are also most active and nutrients are released from the soil particles and organic matter for use by the plant as a result of their activity. Only a portion of the minerals needed for plant growth are supplied in the form of chemical fertilizers; the rest of the plant nutrients are derived from the mineral portion of the soil and the organic matter, as a result of bacterial action.

SOURCE AND SUPPLY OF MOISTURE

How shall the optimum moisture content be maintained? Before considering this question we must examine the fate of water added as rain or by irrigation. Figure 2 shows that the moisture added to the soil may

(1) Run off the surface without entering the soil.

(2) Percolate through and be lost as drainage water.



VARIOUS WAYS BY WHICH WATER MAY BE LOST FROM THE SOIL

(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

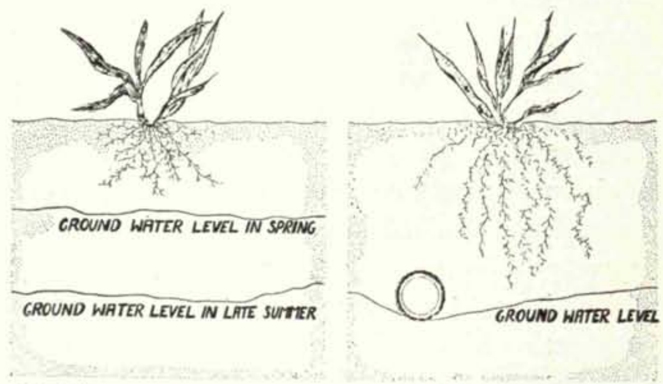
WHATEVER the structure and moisture-holding capacity of the soil, the plant will not use such water unless the soil is occupied by the root system. Roots of turf grasses are stimulated by some conditions and inhibited in growth by others. Poor soil drainage always means scanty root development. This 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.

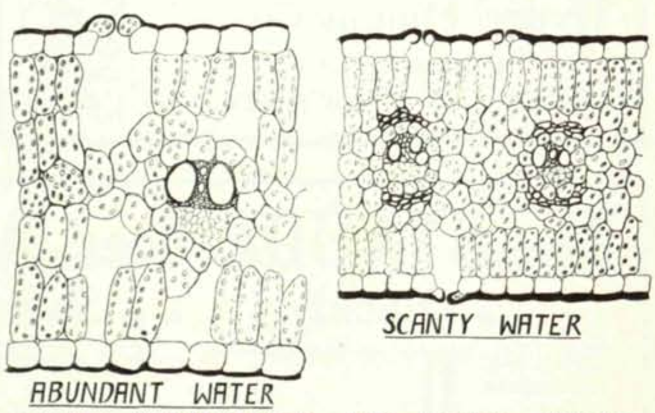
Another factor which greatly influences water absorption is the acidity of the soil. Certain grasses such as the bents, are more tolerant of acidity than others, such as Kentucky blue grass. Nevertheless, it is a well known fact that strong acidity will prevent the formation of root hairs and thus reduce 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.