Moisture Requirements of Grass, With Figures on Rainfall for 1925-1930, Inclusive

The problem of supplying sufficient water to golf course turf for its best growth and development becomes one of supplementing that supplied by nature in the form of rain or snow by some system of artificial irrigation. The solution of this problem requires recognition of the conditions which influence the amount of water that becomes available to the plant, among which are the temperature and humidity of the air, velocity of the wind, run-off and evaporation, the fertility and water-holding capacity of the soil, and probably many other factors.

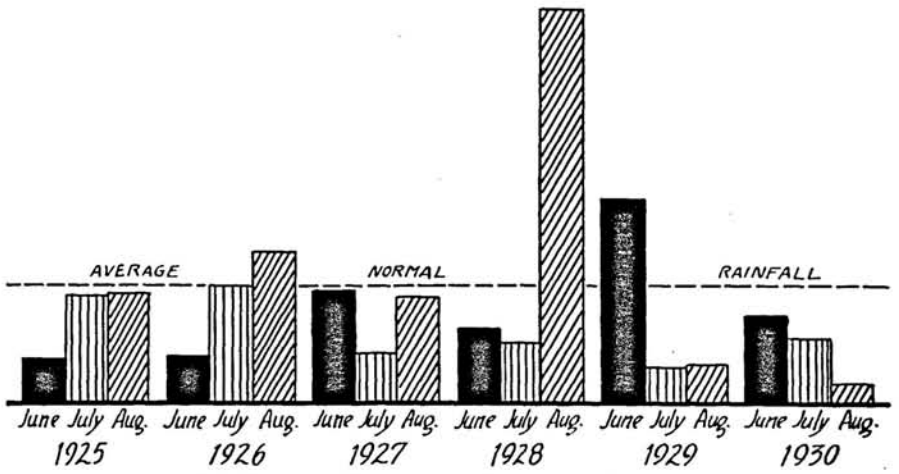
The accompanying rainfall tables for 6 years, from 1925 to 1930 inclusive, are presented to bring out the extreme variability in the amount of moisture supplied naturally in many of the chief golfing districts of the country. Accompanying each table are comments calling attention to some of the points of particular interest. A general comparison of the tables and comments on them clearly show how impracticable it is for anyone to set up definite rules for artificial watering to be carried out successfully without regard for the natural rainfall. Unfortunately it is impossible to show in simple tables the distribution of the total amount of rainfall for each month. The objection to figures such as are given in these tables is that the total number of inches of rainfall in a month may appear to be adequate, whereas, as a matter of fact, the majority of it may have come in a few short downpours which may have been more harmful than beneficial due to excessive run-off. Even with this objection the figures are sufficiently varied and interesting to justify careful consideration.

It is interesting to consider the figures in the accompanying tables in terms of time required to apply the same amounts of water by artificial watering. It takes over 3,000 gallons of water to give a putting green of 5,000 square feet the equivalent of 1 inch of rain. A sprinkler delivering 20 gallons of water a minute would have to run on a putting green of that size 2 hours and 36 minutes to deliver as much water as 1 inch of rainfall. Such a sprinkler in 39 minutes would deliver as much water as fell in rainfall during the entire month of July, 1930, in the St. Louis district. On the other hand, the same sprinkling would have to be continued over 38 hours, or roughly 1¼ hours a day for one month, to deliver as much water as fell naturally in Washington during August, 1928.

Only a part of the rainfall can be used by plants. Some of it runs off the surface without entering the soil where roots may reach it. The loss through run-off is often considerable when a large amount of rain falls in a short time. A quick, hard, dashing rain has the effect of packing the soil at once, thus increasing the run-off, erosion, and loss of plant foods by washing, as well as removing valuable organic matter. A hard rain leaves the soil in such a condition that, upon exposure to a drying atmosphere, it bakes and cracks and causes water to be rapidly lost by evaporation, which is of much importance especially in a hot, dry climate. A gentle slow rain causes no run-off and consequently a greater part of it is absorbed into the soil and becomes available to plants.

The water that enters the soil is, for convenience, classified as *gravitational* water, *available* water, and *unavailable* water. When

soil is saturated by rain or excess watering, the air which normally fills the spaces between the soil particles is displaced by water. When soil is provided with proper drainage a certain amount of water, known as *gravitational* water, soon drains out of saturated soil. Most of the water which remains in the soil after the gravitational water has drained away can, under normal conditions, be used by plants and is therefore termed *available* water. When soils are dry they still contain some water which is held so tightly by the soil particles that plants are unable to use it and it is therefore called *unavailable.* Different soils retain water in different degrees with the result that even though they may have exactly the same amount of rainfall two nearby courses on different types of soil may have decided differences in the amount of water kept in reserve for turf use.



Fluctuations in rainfall at Washington, D. C., during the summer months of six years. The broken line indicates the average normal rainfall for these three months. Such extremes in monthly rainfall as are shown here are likely to complicate the problems of turf maintenance

The supply of available soil water after a good rainfall may, under certain conditions, be adequate for plant growth for long intervals whereas under other conditions it may be rapidly depleted. Much of the loss of available soil water is due to evaporation from the surface. In nature this loss by evaporation is greatly reduced by a mulch of dead leaves or stems, and in cultivated crops it is reduced by a dust mulch created by cultivation. On golf courses where close clipping removes most of the protective layer and where the surface of the soil becomes hard by trampling and by machine wheels, great quantities of water may be lost from the surface of the soil by evaporation. Probably a large proportion of the rain that falls on a hot summer day is lost by evaporation before it can be absorbed into the soil. Especially is this true when it falls on hard, bare surfaces.

Much of the available soil water is taken in by the roots of plants and given off as vapor from the pores in the leaf surfaces. The loss of water from the leaf and soil surfaces is greatly increased by a condition of low relative atmospheric humidity accompanied by summer heat and winds. A hot, dry wind will often cause water to be removed from the leaves as vapor more rapidly than the roots can

absorb it. In this event the plant wilts and may die. Conversely, a cool, humid climate reduces these losses and, in effect, greatly increases the amount of available moisture even though such an increase is not indicated by figures in a rainfall table.

Since clubs expect their courses to be kept in suitable condition for play throughout the entire playing season regardless of variations in the amount of rainfall, adequate provision must be made not only to provide an abundant water supply for periods of drought but also to provide for removal of excess water during rainy seasons. Too much water often causes more damage to golf turf than too little water. An intelligent use of a watering system will provide against the effects of excessive applications of water by artificial means but, as is indicated in the accompanying tables, it is necessary to provide also for frequent excessive rainfalls. If drainage is poor the air spaces in the soil may be choked with water thus preventing a normal growth of grass roots. In addition to affecting the growth of roots it also affects the growth of soil organisms which may have a direct

The severity of the drought of 1930 in the St. Louis district is well illustrated by this view of a fairway of the Westwood Country Club, Clayton, Mo. The dark winding strip through the center of the picture is green turf in a depression through the fairway leading from the putting green in front of the grove of trees in the middle background. Moisture seeping along the depression from the well-watered putting green kept this strip of grass green, while on each side of the strip the grass was completely withered

or indirect influence on the growth of turf. The damage due to poor drainage is often not limited to periods of excessive rainfall, for seepage may ultimately ruin turf weeks after heavy rains occur. The sprinkling of turf, particularly in the case of putting greens where there is a demand from the golfers for more water to keep the greens soft to hold pitch shots, may be so excessive that turf may be ruined by surplus water even in seasons which, according to the rainfall tables, may be classed as dry seasons. Such losses can be largely prevented by improvement of the soil texture and by providing drainage which is adequate to take care of any excess water that may come from rain or careless irrigation as well as from seepage.

Most turf-disease organisms are water-loving. A continued excess of moisture will create conditions at once favorable to the organisms and unfavorable to the turf, thereby throwing the balance in favor of the organisms causing disease. Conditions during the year

1930, when rainfall in many sections was deficient, bear out the truth of this statement. During that year golf courses generally were unusually free from attacks of large and small brown-patch.

An excess of soil moisture prevents a normal development of roots. When the amount of moisture that is required for growth is provided in the surface inch or two, by frequent heavy watering, the roots fail to extend and a very poor root growth results. Shallow-rooted turf is the first to suffer during drought. Not only is the depth of available soil reduced from which water is taken, but the structure of turf grasses grown under such conditions is changed so that the grasses are tender and susceptible to injury and excessive water loss as vapor.

The artificial conditions created for turf grasses on golf courses, especially on the putting greens, further complicate the problem. The removal of the clippings tends to reduce the available moisture. Under the plan of nature they would be left upon the ground to form a protective sheath of organic matter, thus reducing water loss by evaporation, and would eventually become a part of the soil, thus adding to its fertility as well.

The plan of irrigation practiced by the greenkeeper to supplement the natural water supply will determine, to a large extent, the efficiency of the turf grasses in making use of the moisture provided. Due to the variability of rainfall in amounts, time, and manner, it is obvious that a definite schedule for watering can not be adhered to. Turf grasses, in order to be efficient users of water, must have a relatively deep root system so that they will have a larger absorbing depth. Frequent light waterings which wet only the surface inch or two tend to keep the roots confined near the surface, since roots grow toward the moisture. In time of drought such turf suffers greatly unless watered often.

In the following tables are given the monthly and annual rainfall figures, in inches, for the past six years at nine important golfing centers in the United States. The normal (50-year average) for each month is also given. The fluctuation from normal will, in many cases, be found to be considerable, and will serve to emphasize the points brought out in the discussion.

It is interesting to compare the extremes in the nine tables. During the six years listed in the tables the number of months in which the rainfall exceeded 7 inches was as follows: Boston, 1; Chicago, 1; Cincinnati, 4; Detroit, 1; New York, 5; Philadelphia, 2; Pittsburgh, 2; St. Louis, 5; Washington, 2. In all cases these months of excessive rainfall occurred during the growing season and most of them were summer months when a surplus of water was most likely to cause trouble. Leaving out of consideration the three winter months, when the grass is dormant, the tables show that in these six years the number of months when the rainfall was less than one inch was as follows: Boston, 2; Chicago, 1; Detroit, 3; New York, 1; Philadelphia, 1; Pittsburgh, 2; St. Louis, 4; Washington, 6. There were only two months in the growing season at Chicago with extremes in rainfall below one inch or above seven inches, whereas at St. Louis there were nine months with such extremes in rainfall. Frequent extremes in rainfall, as with other climatic conditions, during the time when courses are in play, complicate the problems of turf maintenance.

Boston Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	3.97	2.53	2.67	1.66	3.82	2.77	3.61
February	1.55	5.56	3.28	2.66	3.78	2.23	3.37
March	5.21	2.91	1.19	1.56	2.80	3.02	3.57
April	2.48	1.73	1.36	4.68	7.52	2.09	3.34
May	2.07	3.31	2.50	3.08	2.82	3.39	3.18
June	4.59	1.33	2.43	5.56	2.30	2.24	2.89
July	3.54	6.06	4.77	4.14	1.35	3.36	3.49
August	1.40	3.91	6.73	2.45	2.22	3.03	3.62
September	3.45	1.08	2.43	4.47	0.76	0.26	3.14
October	4.03	3.58	3.77	2.88	2.38	5.83	3.15
November	3.66	4.07	4.71	1.85	3.01	4.09	3.33
December	5.20	3.96	5.22	2.61	4.43	2.99	3.45
Total	41.15	40.03	41.06	37.60	37.19	35.30	40.14

A glance at the table for Boston gives one an idea of more or less the ideal condition as far as rainfall is concerned. During the six years the rainfall was unusually well distributed throughout each year except for a few lean months, July, August, and September in 1929, and September in 1930, which actually did not affect the vegetation greatly. What a great difference between supplying water for a course here as compared with a course at St. Louis during the 1930 season especially! The difference in the cost of watering in two instances such as these is considerable.

New York Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	5.30	2.52	1.95	1.41	2.67	2.58	3.66
February	1.92	5.46	3.33	4.35	4.30	3.40	3.82
March	3.25	2.52	1.18	2.54	3.51	2.16	3.64
April	1.73	1.76	2.66	4.71	5.76	2.01	3.23
May	2.43	2.45	3.67	1.98	3.64	2.89	3.24
June	2.31	2.47	3.13	6.12	2.30	2.60	3.33
July	6.05	7.47	5.93	7.72	0.98	5.05	4.24
August	1.64	7.57	8.05	4.26	1.45	3.43	4.33
September	1.87	5.51	3.84	3.36	4.05	1.37	3.39
October	4.13	5.11	8.82	1.27	5.16	1.76	3.53
November	2.56	3.12	3.95	2.16	2.08	5.43	2.96
December	3.33	3.72	3.39	0.85	3.23	2.65	3.62
Total	36.52	49.68	49.90	40.73	39.13	35.33	42.99

A study of the rainfall table for New York shows that during the summer of 1929, May to September, inclusive, worse drought conditions prevailed than for the same period in 1930. Three inches more rain fell with more even distribution for that period in 1930 than for the same period in 1929 and the greater part of it came when needed the most. During June and July of 1928 a total of nearly 14 inches fell, over four times as much as during the same months in 1929, creating conditions favorable for ravages of turf diseases. Turf in the New York district was severely damaged during that period in 1928, whereas little damage occurred in 1929.

Pittsburgh Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	3.16	2.85	3.52	1.30	3.33	1.67	3.05
February	1.91	3.47	3.97	3.07	2.62	3.12	2.62
March	1.61	1.73	3.20	4.25	2.15	2.82	3.03
April	1.43	1.46	3.15	4.05	4.29	2.60	2.92
May	3.42	2.10	3.74	1.09	5.38	1.95	3.21
June	2.11	1.20	2.77	7.73	2.21	3.41	3.81
July	3.81	1.72	6.34	4.93	3.50	1.33	4.05
August	0.96	2.95	1.86	3.10	1.79	1.10	3.23
September	1.58	7.45	2.18	1.02	1.05	0.74	2.58
October	4.09	4.12	4.09	1.22	5.07	1.17	2.52
November	2.70	3.27	5.18	1.91	3.38	1.02	2.29
December	1.40	3.12	3.16	1.18	2.15	1.72	2.86
Total	28.18	35.44	43.16	34.85	36.92	22.65	36.17

Of the six years given for Pittsburgh only two have shown a considerable deficiency of rainfall below the normal; they were 1925 and 1930, having deficiencies of approximately 8 and 14 inches, respectively. In 1930 the only month which showed an excess over normal was February. Succeeding months, all of which were deficient, exhausted the normal supply and caused vegetation to suffer. The rainfall steadily decreased and turf went into the winter in a dry condition. A somewhat similar condition occurred in 1925 but was reversed in 1926 and 1927.

Cincinnati Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	1.91	2.65	4.44	1.65	4.60	4.25	3.48
February	2.33	3.35	2.20	3.23	1.58	2.95	2.99
March	2.26	2.56	3.65	1.31	2.51	1.91	3.89
April	1.84	4.99	4.77	3.66	3.98	2.05	3.12
May	2.05	4.65	4.67	0.76	7.74	1.01	3.70
June	1.89	2.61	4.22	9.07	4.98	0.98	3.66
July	9.13	10.02	3.09	4.61	4.54	2.46	3.31
August	3.45	6.52	3.54	2.85	1.80	1.24	3.41
September	3.67	4.10	3.28	1.27	5.17	4.38	2.65
October	4.24	4.49	3.07	3.18	3.24	0.78	2.51
November	5.75	1.45	6.46	3.25	4.19	1.28	2.85
December	0.67	2.47	3.48	2.56	2.43	1.20	2.98
Total	39.19	49.86	46.87	37.40	46.76	24.49	38.55

In studying the rainfall tables for Cincinnati one is struck by the difference in rainfall for the years 1929 and 1930, especially during the months of April to November, inclusive. The effect of this on vegetation is at once apparent. How much simpler the greenkeeper's problem of watering was during 1929 as compared with 1930! Then consider the month of May, 1928, with only ¾ inch. The reason that deficiency then was not serious is that the month preceding was over normal and stored a certain amount of water in the soil. The month following had a great excess and more than replaced all that was lacking during the previous month.

Philadelphia Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	4.68	2.85	1.88	1.91	2.70	3.15	3.30
February	1.66	3.18	3.62	4.00	4.24	3.65	3.32
March	3.15	1.96	1.11	2.10	2.22	2.58	3.39
April	2.43	1.81	3.66	5.55	6.44	1.64	3.05
May	2.36	2.31	1.75	2.19	2.28	3.25	3.26
June	1.16	2.81	3.48	6.77	2.74	4.96	3.24
July	4.99	8.40	4.50	3.60	1.53	4.06	4.15
August	2.01	5.99	7.27	5.47	3.22	1.51	4.62
September	1.89	4.88	2.59	3.61	6.51	2.57	3.14
October	4.14	4.11	5.71	0.73	3.59	1.74	2.81
November	2.97	3.07	3.59	1.94	3.11	2.36	2.70
December	0.96	3.54	3.99	1.50	2.98	2.50	3.43
Total	32.40	44.91	43.15	39.37	41.56	33.97	40.41

The rainfall tables for Philadelphia reveal a striking contrast to the conditions at Washington for the year 1930. Only two months, April and August, fell appreciably below normal. Three out of the six years listed show a rainfall above the normal. The two years 1925 and 1930, which had a deficiency, had the greater part of the rainfall during the growing season, when it was most needed.

Detroit Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	1.08	2.23	1.98	1.36	4.26	3.85	2.07
February	2.10	4.05	1.48	1.34	1.36	1.67	2.18
March	3.44	2.71	1.53	1.99	2.85	1.98	2.40
April	1.42	3.04	2.38	1.96	5.65	3.60	2.46
May	1.21	2.09	5.58	2.57	3.59	3.15	3.21
June	4.26	2.81	2.30	3.83	2.55	2.70	3.56
July	6.94	1.24	3.59	4.07	2.65	0.50	3.32
August	2.81	8.33	1.06	2.02	0.52	0.90	2.78
September	4.54	5.67	3.44	1.68	1.75	2.97	2.90
October	4.35	3.11	1.65	1.82	3.99	1.80	2.38
November	3.52	2.59	5.29	2.69	3.20	1.72	2.44
December	1.68	1.39	2.39	1.38	4.79	1.10	2.35
Total	37.35	39.26	32.67	26.71	37.16	25.94	32.05

While Detroit was not as badly affected by the drought of 1930 as certain other sections were, still there was a rather serious situation during the growing season. For instance, the rainfall during April and May was only slightly above normal, which did not provide an excess for the following months, which fell below normal. However the situation was not as bad as it appears in comparing this table with tables for other cities given, because there is the compensating effect of lower temperatures and higher humidity than occur in regions farther south and more inland, thus, in effect, providing much higher available moisture than the figures show. Thus a total rainfall of 40 inches at Cincinnati may not support any more vegetation than a much smaller amount at some lake city where the rate of evaporation is low and the relative humidity high.

Chicago Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	0.68	1.35	1.15	0.73	3.93	2.23	1.90
February	1.62	2.92	0.75	1.57	0.54	1.42	2.14
March	1.51	3.14	2.69	1.50	5.23	2.82	2.58
April	3.15	1.96	6.01	2.34	4.79	2.30	2.78
May	1.59	2.73	4.40	1.59	2.29	2.16	3.54
June	4.53	7.62	2.55	6.97	4.96	2.49	3.30
July	2.47	3.21	2.94	2.95	2.18	2.63	3.33
August	2.09	0.99	3.17	5.03	3.49	1.17	3.21
September	3.19	5.03	6.72	1.87	3.03	1.29	3.14
October	3.72	1.67	1.77	2.74	3.06	2.81	2.53
November	2.57	3.97	4.66	4.00	1.47	1.75	2.37
December	1.21	0.87	2.74	2.63	1.84	0.27	2.04
Total	28.33	35.46	39.55	33.92	36.81	23.34	32.86

The annual rainfall during the six years shown for Chicago fell below normal only on two occasions, in 1925 and 1930. The drought of 1930 was much more severe due to the fact that during the growing season every month fell below normal with no compensating period of greater-than-normal rainfall to build up the diminished supply of moisture in the soil. Compare this with the year 1926. The rainfall in August, 1926, fell below an inch, which ordinarily is considered a serious deficiency. June of that year, however, had more than twice normal rainfall; July was almost at the normal; and September almost doubled its quota, thus replenishing the normal moisture reserve in the soil.

St. Louis Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	0.53	1.69	3.66	1.91	2.11	5.70	2.34
February	2.19	2.52	0.56	2.43	0.88	2.35	2.56
March	1.50	3.95	7.67	2.27	5.33	0.99	3.38
April	2.70	4.42	6.30	3.02	6.99	1.32	3.81
May	1.48	1.58	9.21	2.18	10.09	1.69	4.34
June	4.84	1.72	2.59	7.25	3.65	2.63	3.82
July	1.78	0.54	2.79	6.66	2.67	0.25	2.98
August	2.75	1.83	2.60	4.83	3.40	0.28	2.99
September	4.59	7.40	2.93	1.70	1.71	3.51	3.46
October	4.32	3.84	4.65	2.24	4.99	1.84	2.72
November	4.09	2.71	5.56	1.90	1.41	1.77	2.83
December	1.46	1.15	2.31	2.22	3.07	0.90	2.21
Total	32.23	33.35	50.83	38.61	46.30	23.23	37.44

Fairway turf at St. Louis in 1930 was badly injured where water could not be supplied. Crab grass and other weeds were checked and turf lay dormant most of the summer. Although turf on putting greens had to be watered well and often, it was favored by the relative mildness of brown-patch attacks due to the deficiency of natural moisture. There were only two months in 1930, January and September, in which rainfall equalled the normal, while the total for

both July and August was only slightly more than ½ inch. A comparison of the total of 23.23 for 1930 with 50.83 for 1927 shows a spread of over 27½ inches, which is more than the total annual rainfall for 1930.

Washington Rainfall

	1925	1926	1927	1928	1929	1930	Normal
January	4.44	3.60	1.20	2.63	2.16	2.85	3.55
February	0.98	4.17	3.34	2.69	3.19	1.64	3.27
March	1.60	2.07	1.27	2.17	2.64	2.26	3.75
April	2.44	0.79	4.96	4.49	6.10	3.12	3.27
May	1.67	2.22	2.21	4.00	2.29	1.81	3.70
June	1.53	1.66	4.01	2.66	7.41	3.19	4.13
July	3.82	4.20	1.82	2.17	1.29	2.30	4.71
August	3.89	5.50	3.84	14.41	1.30	0.62	4.01
September	3.05	6.80	1.19	4.29	4.32	0.76	3.24
October	4.86	4.23	5.33	0.67	4.82	0.28	2.84
November	3.53	5.29	2.65	2.01	1.70	0.79	2.37
December	1.07	3.02	3.51	1.21	2.20	2.04	3.32
Total	32.88	43.55	35.33	43.40	39.42	21.66	42.16

The unusual feature of the rainfall at Washington, D. C., in 1930, is the fact that during no month of the year was it equal to normal. During the months of August, September, October, and November the total rainfall for the period was only 2.45 inches, an average of a little more than ½ inch a month—a surprising deficiency of moisture. Compare this with the year 1925, which was considered a dry year at the time, and with 1928, which had an excess of moisture over the normal. The deficiency in 1925 was due to the lack of normal rainfall during the early part of the growing season and the winter months preceding. Due to the lack of natural moisture there was a condition of low humidity which retarded the development of fungous diseases but at the same time further reduced the total available moisture by increasing transpiration and evaporation. In August, 1928, there was a total rainfall of 14.41 inches. Over half of this amount fell in the space of 24 hours, and during one 30-minute period of that time 1.11 inches of rain fell. Actually more harm than good resulted from this rain, which is only one extreme instance of the many that occur. In all probability the amount that entered the soil was very small in proportion to the amount that fell. Somewhat similar cases are noticed in April and June, 1929, at Washington, and again in September and October. The rainfall for the other months during 1929 was below normal, so that actually the drought of 1930 began in 1929 with an accumulated deficiency from that year.

Trees lacking in vigor often respond to applications of plant food which aid considerably in restoring them to a healthy condition. This does not always eliminate the necessity of pruning or other surgical work, but so much importance is attached to plant foods that considerable surgery might be eliminated by enriching the soil.