# Effect of Temperature and Moisture on Occurrence of Brownpatch

By Arnold S. Dahl

The conditions tending to encourage the development of the brownpatch disease of turf have been a subject of much speculation and theorizing in recent years. The cause of the disease is specific; it has been proved to be the fungus *Rhizoctonia solani*. This fungus is usually present in the soil, and when conditions are favorable it becomes active and attacks the grass.

It has been generally observed that brownpatch is most prevalent during hot, wet periods of the summer, and that with a change from these conditions the fungus usually becomes inactive. There are so many other conditions that encourage attacks of the disease that it is impossible to predict just when the disease will be active without taking into consideration all conditions that might be influential. Many greenkeepers have attempted to predict its occurrence and many have been able to do so with a certain degree of accuracy. An experienced greenkeeper will express the opinion that it is brownpatch weather, and he will probably be right; but, if one were to question his reason for the statement, he could not tell exactly what the conditions are that will cause the disease. Often, however, the disease occurs when there is no characteristic "brownpatch weather," and as a result greenkeepers are apt to become confused. It is impossible to select a particular condition and to forecast the occurrence of the disease by that condition alone. Attempts have been made at such forecasting but have not proved successful.

## Effect of Temperature

Brownpatch is more responsive to temperature changes than to any other environmental condition. The correlation of temperature and occurrence of the disease is readily noticed by greenkeepers because they themselves are directly affected by changes in temperature. Since brownpatch was first observed it has been noticed that the disease occurs usually when the temperature is high, and that when the temperature becomes cooler for a period the fungus becomes inactive.

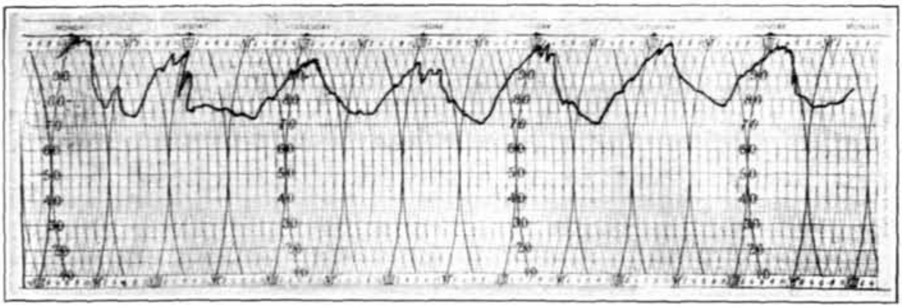
The optimum temperature for the occurrence of brownpatch is dependent on two factors: (1) the optimum temperature for the fungus (the temperature at which the fungus grows most rapidly); and (2) the influence of temperature on the resistance of the grass to attacks by the fungus.

Although a fungus has an optimum temperature at which it makes its best growth, it will also grow rapidly at temperatures higher or lower than the optimum. In 1924 and 1925 experiments were conducted in a laboratory of the University of Wisconsin to determine the effect of temperature on the growth of the brownpatch fungus. The purpose of these experiments was to find the limits of temperature between which the fungus grows as well as to find the temperature at which it makes its best growth. The results showed that the optimum temperature for the fungus is about 83 degrees (Fahrenheit). There was rapid growth at 72 degrees and fairly good growth at 94 degrees. Below 61 degrees there was very little growth and none at all at 39 degrees. The fungus also failed to grow at 104 degrees. From this study it was apparent that the optimum temperature range for the activity of the fungus is from about 72 degrees to 94 degrees, and that above or below this range very little growth takes place. These results, confirming the observations which had been made up to that time, were published in the June, 1926, number of the Bulletin, together with a discussion of several other factors that affect the occurrence of brownpatch.

The optimum temperature for the fungus, however, is not always the optimum temperature at which parasitism takes place. The condition of the grass plays an important part. A high temperature may be unfavorable for the plant and favorable for the fungus, so that the leaves of the grass are easily invaded by the fungus. The weaker the grass the more easily is it invaded, and therefore the optimum temperature for parasitism may be above the optimum temperature for the fungus. It is necessary to point out here that temperature alone does not determine the occurrence of disease, but that moisture, light, and general condition of the plant also play an important part. Attacks of the disease often occur at temperatures higher and lower than the optimum, and often attacks do not occur even when temperature is at the optimum.

#### Field Observations on Effects of Temperature

Beginning in 1924 records of climatic conditions and occurrence of disease have been kept at the Arlington turf garden, for the summer period from June to mid-September. A continuous record of



**Record of air temperature taken from hygro-thermograph chart. These temperatures occurred over a plot at Arlington turf garden from July 21 to July 28, 1930. On each day during this period severe attacks of brownpatch occurred on the garden. New patches of the disease were evident on each day. Note that the temperature did not fall below 70 degrees at any time during the period.**

temperature and relative humidity has been obtained by means of a recording hygro-thermograph. These records have been checked with the records of the United States Weather Bureau and have been found to be closely in agreement. A record of rainfall has also been kept at the turf garden. In conjunction with the records of climatic conditions the occurrence of brownpatch has been carefully recorded each day over the period. The records note whether the disease is very active or only slightly active. The records of temperature confirmed the results of the laboratory work indicating that the disease occurs during the hottest weather of the year and that as soon as the temperature rises and remains above 80 degrees for some length of time the disease is apt to occur. The disease rarely occurred when the temperature remained below 75 degrees throughout the day.

Later L. S. Dickinson, of Massachusetts State College, reported observations which led him to believe that the disease occurs only after a fall in temperature with a subsequent rapid rise to the optimum temperature range. He reported that the temperature must fall to somewhere between 64 and 68 degrees and then rapidly rise to between 80 and 85 degrees in order that attacks of disease might occur. He attributes this to the fact that the resting bodies of the fungus require chilling to between 64 and 68 degrees to germinate. He further states that the fungus attack of the grass ceases above 90 degrees, and that below 62 degrees the fungus growth is destroyed. These results did not check with the observations that had been made at Arlington turf garden over a period of years from 1924.

TABLE 1.—OCCURRENCE OF BROWNPATCH AT ARLINGTON TURF GARDEN OVER THE 5-YEAR PERIOD 1927 TO 1931 AT VARIOUS TEMPERATURE RANGES

| Temperature ranges in degrees Fahrenheit | Number of days included | Occurrence of the disease | |
|---|---|---|---|
| | | Number of days | Percentage of days |
| *Maximum temperatures* | | | |
| 60 to 64 | 1 | 0 | 0 |
| 65 to 69 | 8 | 2 | 25 |
| 70 to 74 | 11 | 3 | 27 |
| 75 to 79 | 40 | 17 | 42 |
| 80 to 84 | 74 | 42 | 57 |
| 85 to 89 | 90 | 61 | 67 |
| 90 to 94 | 82 | 59 | 71 |
| 95 to 99 | 53 | 38 | 72 |
| 100 and over | 28 | 24 | 85 |
| Total | 387 | 247 | 64 |
| *Minimum temperatures* | | | |
| Below 60 | 64 | 17 | 27 |
| 60 to 64 | 95 | 57 | 60 |
| 65 to 69 | 106 | 72 | 67 |
| 70 to 74 | 103 | 84 | 82 |
| 75 to 79 | 18 | 15 | 83 |
| 80 to 84 | 0 | 0 | 0 |
| *Minimum temperatures (summarized)* | | | |
| Below 64 | 137 | 58 | 42 |
| 64 to 68 | 112 | 77 | 68 |
| Above 68 | 137 | 110 | 80 |

In an analysis of temperature records for a 5-year period (1927 to 1931) at Arlington turf garden the maximum and minimum temperatures were tabulated from the charts of the recording instruments. The relation of the occurrence of brownpatch to various ranges of maximum and minimum temperatures is shown in Table 1. The ranges of temperature presented in the table, it will be noted from the first column, are 5-degree ranges. In the second column is shown the number of days included within the respective 5-degree ranges of temperature. In the third column is shown the number of these days on which brownpatch occurred on the turf garden. The percentage of the number of days on which the disease occurred, to the total number of days on which observations were made, is shown, for the respective 5-degree ranges of temperature, in the fourth column.

The table shows that, during the period over which these records were taken, brownpatch occurred 64 per cent of the time. This percentage would probably vary greatly in different parts of the country. It may also vary on different courses in the same locality, depending on the variety of grass, soil conditions, locations of greens, and cultural practices. The high percentage of days on which brownpatch occurs at Arlington turf garden because of its geographical location, makes it an ideal place for a study of this kind.

It may be noted from the table that the higher the temperature the greater the percentage of days on which disease occurred. It shows that when the maximum temperature was over 100 degrees, as it was on 28 days during the 5-year period, brownpatch occurred on 24 of those days, or 85 per cent of the time. When the maximum temperature is above 90 degrees there is the chance that brownpatch will occur about 74 per cent of the time. The fungus does not grow well above 100 degrees, and that temperature may be reached for only a short time during the day; but it is probable that the higher the maximum temperature the higher the temperature has been during most of the day, and probably during the night as well. At least it is definite that brownpatch rarely occurs when the maximum temperature is below 75 degrees.

Analysis of the minimum temperatures also shows that the higher the minimum temperature the more frequent the occurrence of this disease. The table shows that when the minimum temperature was above 70 degrees brownpatch occurred 82 per cent of the time; below 60 degrees the disease occurred only 27 per cent of the time. The earlier report stated that the fungus did not grow vigorously below 60 degrees and did not reach a growing state until the temperature rose to 65 degrees or 70 degrees, so that one would not expect the disease to occur at the lower temperatures. The disease occurs with more frequency when the minimum temperature remains above 70 degrees than it does when the minimum temperature falls below 70 degrees. Therefore it is apparent that the fungus does not need a chilling temperature to become active. In the table the records are also tabulated for minimum temperatures of 63 degrees and below, 64 to 68 degrees, inclusive, and 69 degrees and above. This indicates that the fungus is most active without a chilling period. It is evident from the table that while the fungus is more active at the higher temperatures, there is no definite point above which it occurs and below which it does not occur. It indicates that other factors are also important in the occurrence of the disease.

### Effect of Temperature of Water

Inquiries have been received as to the effect watering putting greens with cold water from deep wells has on the temperature of the turf. It has been suggested that the decreasing of the temperature of the turf might make conditions more favorable for fungus development particularly on hot days, and others have suggested that watering greens during the night might lower the temperature of the turf to such an extent that brownpatch might not develop.

Experiments were made to lower the temperature of turf by means of ice water. It was found in several experiments that applying ice water directly from a sprinkling can held close to the turf lowered the temperature an average of 9 degrees. In the different tests the decrease in temperature varied from 5 degrees to 12 degrees. The tests were made both early in the morning and during the heat of the afternoon, and there was not a great difference noticed in the decrease when the initial temperature was either high or low. The usual watering of a green lowered the temperature 2 degrees. In one test ice water was sprinkled through a regular sprinkler from a power spray machine. The temperature of the water in the spray tank was 32 degrees; at the end of 100 feet of ¾-inch hose, 46 degrees; when sprinkled through the air and caught in a pan, it was 76 degrees; and the turf, after sprinkling an amount equal to 2½ inches of rainfall, was 76 degrees. The temperature of the turf at the beginning of the experiment was 78 degrees and the air temperature was 80 degrees. This experiment shows that water quickly approaches air temperature when sprinkled through the air and that cold water does not greatly decrease the temperature of turf. Sprinkling with ice water did not decrease the temperature of the turf any more than the usual watering, and that was only 2 degrees. When a decrease in temperature did take place through the addition of water, the original temperature quickly returned. From these experiments it has been concluded that watering greens with cold water has no appreciable effect on the temperature of the turf, and has no effect on the development of diseases except that the added moisture may cause more favorable conditions for fungus growth, and some well water may contain chemicals in solution that in time may affect grass growth.

### Laboratory Experiments with Temperatures

Experiments were carried on in a laboratory at the University of Wisconsin in 1931 which were devised to give more facts as to the relation of temperature to the growth of the fungus. Resting bodies (sclerotia), were used in these experiments to find what their reaction would be to constant and changing temperatures. This work was planned with the view of correlating it with the observations in the field. In these experiments six strains of the fungus which had been isolated from grass were used together with strains isolated from diseased plants of cabbage, sugar beet, cotton, potato, and pea. All of these strains were the same fungus, *Rhizoctonia solani,* and all were proved pathogenic (capable of producing brownpatch) by experiments in the greenhouse. However, there were differences in their vigor in attacking grass. Five of the strains, three from grass, and those from cotton and peas, were very pathogenic; two strains, both from grass, were medium; and three, those from cabbage, potato, and sugar beet, were only slightly pathogenic.

The resting bodies of these strains were germinated in sterile plates containing a suitable nutrient medium at different temperatures from 46 degrees to 104 degrees. The time that elapsed from the transfer of the resting bodies to their nutrient medium, until their germination, was recorded. It was found that the optimum temperature for germination was 83 degrees, and the average germination time at that temperature was 2 hours and 36 minutes. The resting bodies which germinated most rapidly were of the strains which were the most pathogenic. The sclerotia also germinated quickly at 90 degrees and 97 degrees, and at 75 degrees and 68 degrees. The germination time at 90 degrees and 97 degrees was less than at 75 degrees and 68 degrees, respectively. The average time of germination at 97 degrees was 48 minutes less than at 68 degrees. While the resting bodies are able to germinate easily at 97 degrees, the growth of the fungus after germination at that high temperature is extremely slow. The resting bodies also germinated slowly at 53 and 60 degrees. The limits for germination of the resting bodies are 46 degrees and 104 degrees. At these temperatures the resting bodies did not germinate for several days.

In 1930 Dickinson reported results of laboratory work with resting bodies of the fungus. From his experiments he concluded that the resting bodies required chilling in order to germinate and make their best growth. He stated that the resting bodies must be chilled to between 64 and 68 degrees and subsequently brought to a higher temperature before they germinated. As these results were at a variance with results that had previously been published and with observations that had been made over a period of years, they were also checked in this laboratory work.

Experiments were thus carried on in which the resting bodies were chilled at 66 degrees for 1 hour. The plates were placed in compartments at the desired temperatures and left there until they reached the temperature of the compartments. Then they were chilled for 1 hour and immediately returned to the original temperature. In general, the chilling did not decrease the time of germination, but in most cases increased it. Only with one strain did chilling decrease the time. With a starting temperature of 97 degrees, two strains germinated more quickly when chilled. However, in the case of 97 degrees the chilling carries the temperature of the culture through the optimum to the chilling temperature, and again through the optimum to the initial temperature, which accounts for the faster germination of the culture when chilled.

In all of the experiments there was a difference in the behavior of individual cultures. Some of the resting bodies germinated quickly and a few did not germinate at all. It was found that the percentage of germination of the sclerotia was greater when not chilled at the beginning temperatures of 75 and 83 degrees. At 97 degrees, however, the percentage of germination of the chilled was greater than the unchilled. Here, again, the chilled sclerotia, by passing through the optimum temperature, were given a condition favorable to germination, while those which were kept at 97 degrees constantly did not have that advantage. Experiments were made in which the sclerotia were chilled from initial temperatures of 75 degrees, 83 degrees, and 97 degrees, to temperatures of 59 degrees, 66 degrees, 70 degrees, and 73 degrees. In most cases, when chilled from 75 and 83 degrees to any of the chilling temperatures, the percentages of germination were less. When the initial temperature was 97 degrees the chilling increased to percentage of germination at all of the chilling temperatures of 59 degrees, 66 degrees, 70 degrees, and 73 degrees.

Experiments were also conducted to determine if the rates of growth of the fungus would be increased by chilling to any point. In these tests the cultures were first placed in a beginning temperature and then chilled for 1 hour and then returned to the initial temperature. The initial temperature was 83 degrees and the chilling temperature was 66 degrees. Eleven strains were used in these experiments and it was found that there was a variation in the behavior of the strains. At the end of 3½ hours only in the case of one strain did chilling increase the growth. After 17 hours seven of them had made their best growth when kept at a constant temperature, three had made their best growth when chilled, and one had remained unchanged. Thus in two of the cases where chilling increased the growth after 17 hours the effect took place after the resting bodies had germinated. In the averages for all the strains, the growth of the unchilled was 15 per cent greater than the chilled.

Three strains of the fungus isolated from grass were further tested in the same way. Initial temperatures of 75 degrees, 83 degrees, and 97 degrees were again used and the resting bodies were chilled from each of these temperatures to 59 degrees, 66 degrees, 70 degrees, and 73 degrees. It was found that in most cases the chilling had adverse influence on the growth of the fungus, no matter to what temperature it was chilled. This was true when the initial temperature was 75 degrees or 83 degrees. When the initial temperature was 97 degrees chilling to any of the chilling temperatures usually resulted in increased growth.

In another series of tests old sclerotia were compared with young sclerotia; these tests showed that, whether young or old, chilling did not increase the amount of growth in either 3½ or 17 hours.

### Effect of Moisture

Many observers have noted that brownpatch occurs more frequently during muggy weather and during seasons when there is much rainfall. An analysis of the records of moisture has shown that the occurrence of brownpatch can be correlated with moisture only in a general way. Although moisture is one of the important factors which influence the occurrence of disease, the methods of measuring and recording the moisture relationship are imperfect and for that reason definite correlations are not possible.

TABLE 2.—OCCURRENCE OF BROWNPATCH AT ARLINGTON TURF GARDEN OVER THE 3-YEAR PERIOD 1929 TO 1931 AT VARIOUS MAXIMUM AND MINIMUM RELATIVE HUMIDITIES

| Relative humidity | Number of days included | Occurrence of the disease: Number of days | Occurrence of the disease: Percentage of days |
|---|---|---|---|
| Maximum below 80 per cent | 29 | 14 | 48 |
| Maximum above 80 per cent | 242 | 152 | 63 |
| Minimum below 50 per cent | 166 | 108 | 65 |
| Minimum above 50 per cent | 96 | 72 | 75 |

As in the case of the daily records of temperature taken at the Arlington turf garden, so also daily records of maximum and minimum relative humidity there have been taken, and in Table 2 are presented figures representing the relation of the occurrence of brownpatch at the garden to the relative humidity during the 3-year period 1929 to 1931. Relative humidity is the amount of moisture in the air in relation to what the air would contain if it were at the saturation point; it is expressed in percentage. The number of days on which the maximum relative humidity was above 80 per cent was recorded, also the number of days on which it was below 80 per cent, and these are shown in the second column of the table. In the third column is shown the number of days on which the disease occurred during the respective conditions. In the fourth column is shown the percentage borne by the number of days of the occurrence of the disease to the total number of days in each case. Similarly figures are presented for conditions pertaining to minimum relative humidities below and above 50 per cent.

From the figures obtained it would appear that when the maximum relative humidity is above 80 per cent there are 63 chances in 100 (63 per cent) that the brownpatch disease will be active, while below 80-per-cent relative humidity there are only 48 chances. It would also appear that where minimum relative humidity is above 50 per cent there are 75 chances in 100 that the disease will be active, while below 50 per cent the disease occurs 65 per cent of the time. These percentages show that while relative humidity may have some influence on the occurrence of the disease it is not a true measure of that factor, because so much of the disease occurs when the relative humidity is low.

An attempt was made to correlate the occurrence of dew with the presence of the disease, but it was found that it was impossible to tell from the available records whether or not dew had been present. There are many factors that influence the formation of dew, among which are relative humidity, falling temperature during the night, presence of clouds in the sky, velocity of the wind, and moisture in the soil. Determinations of the dew point at various hours of the nights apparently could not be correlated with the occurrence of disease.

TABLE 3.—OCCURRENCE OF BROWNPATCH AT ARLINGTON TURF GARDEN IN 1931 WHEN EVAPORATION AT NIGHT WAS BELOW AND ABOVE 30 CUBIC CENTIMETERS

| | Number of days included | Occurrence of the disease: Number of days | Occurrence of the disease: Percentage of days |
|---|---|---|---|
| Below 30 cubic centimeters | 82 | 66 | 80 |
| Above 30 cubic centimeters | 25 | 16 | 64 |

Records of evaporation of water at the garden were kept during the summer of 1931. Evaporation during the day showed no influence on the occurrence of the disease but it may have influenced the severity of the attacks which occurred. The evaporation during the night, however, could in a general way be correlated with occurrence of the disease. The evaporation of water is influenced by temperature, relative humidity, and velocity of wind. Therefore, it is to be expected that when evaporation is great the greens would be dry and less brownpatch would occur. This proved to be the case, as shown by Table 3. When the loss of water was less than 30 cubic centimeters brownpatch was active 80 per cent of the time, and when the loss was above 30 cubic centimeters the percentage dropped to 64.

TABLE 4.—OCCURRENCE OF BROWNPATCH AT ARLINGTON TURF GARDEN IN RELATION TO RAINFALL DURING JUNE, JULY AND AUGUST OF THE YEARS 1929, 1930, AND 1931

| | 1929 | 1930 | 1931 |
|---|---|---|---|
| Rainfall during June, July, and August | 11.66 inches | 7.14 inches | 14.66 inches |
| Percentage of this rainfall in the 3-year total | 35 per cent | 21 per cent | 43 per cent |
| Number of days during the 3 months on which brownpatch occurred | 43 days | 24 days | 52 days |
| Percentage borne by the number of days of annual occurrence to the total number of days of occurrence during the 3 years | 36 per cent | 20 per cent | 43 per cent |
| Proportion of number of attacks of brownpatch to inches of rainfall | 3.68 | 3.36 | 3.54 |

Table 4 shows the relation between rainfall and the occurrence of brownpatch at the garden. The records of the years 1929, 1930, and 1931 are tabulated and the percentages listed are based on the total rainfall and the total number of times the disease occurred during the 3-year period. This analysis shows a definite correlation between the rainfall and the number of days on which the disease occurred. As seen in the table, 1929 had 35 per cent of the 3-year total of rainfall and 36 per cent of the total number of days on which the disease occurred in the 3 years. The year 1930 had 21 per cent of the rainfall and 20 per cent of the disease, and 1931 had 43 per cent of the rainfall and 43 per cent of the disease. It was calculated from this table that the proportions between the amount of rainfall and the number of disease attacks during the years 1929, 1930, and 1931 were 3.68, 3.36, and 3.54, respectively. Although there is a great difference between the amount of rainfall and the number of disease attacks in the three years, there is close agreement in the proportion of rainfall to disease. This indicates that the greater the amount of water in the soil for a considerable period the greater the amount of disease that will occur. It has been noted on greens that those which are overwatered are troubled with disease frequently much more than those which are underwatered. For that reason great care should be taken that greens do not have too much water.

Although moisture is necessary in order that the brownpatch fungus may attack grass, the analyses of moisture records as here given show that it is not possible to predict the occurrence of the disease by these records. The reason for this may be that the soil moisture is the most important factor, and this is not measured by any of the methods that have been used. The amount of moisture in the air and the rate of evaporation are also factors which must be considered. The disease may thus occur when one factor is favorable and another unfavorable, so that it is practically impossible with present information to determine which factor is most responsible for the encouragement of the attack of the disease.