tices. Therefore it is not possible to select a resistant strain and then have it remain resistant regardless of cultural practices. The most desirable turf is produced by a strain of grass which is naturally resistant, treated in such a way that conditions are always unfavorable for injury from any source. All of the grasses used on putting greens must be treated with fungicides for fungus diseases, the amount and frequency of the fungicidal treatments varying with the natural resistance of the grasses together with the conditions under which they are growing.

DISEASE CONTROL WITH CULTURAL METHODS

The selection of resistant varieties or strains of plants is the first step in controlling diseases; but that method would be ineffective if the occurrence of disease was not discouraged by other means. The first attempts to control plant diseases, as referred to on page 99, led to the development of certain cultural practices which served to decrease greatly the occurrence or severity of diseases. Many of the cultural methods devised for controlling diseases of farm crops can not be applied to golf course practices, because of the wide difference between cultural methods used in handling certain annual or biennial farm crops and the care of turf which is planted with the view to being more or less permanent. On the other hand, there are many cultural practices suitable on golf courses that would be impractical on a farm.

To understand the value of cultural practices in disease control one may therefore take a lesson from the farmer. Practices of this nature widely used by farmers are crop rotation, drainage, irrigation, application of lime and fertilizers, proper preparation of the seed bed, cultivation to create a mulch to prevent loss of soil moisture, seed selection in order to guard against obtaining seed from disease-infested areas, and planting at a time to avoid disease attacks. Further, after the plants are up, removal of infected plants or parts of plants, prevention of wounds on the plants, and avoidance of disseminating the parasite, are common practices that prevent certain diseases from becoming more serious.

After harvest it is necessary to burn the crop remains and other refuse to control some diseases. The destruction of wild host plants and of complementary host plants of the causal organism is also practiced. In general, crops are not planted in locations where diseases are apt to occur, such as in fields where the previous crop was badly infested, or on sites where topographical conditions are favorable for the development of the causal organisms.

The above is a general review of many ways in which the occurrence of a large number of diseases may be discouraged. A disease can not usually be completely controlled by cultural practices alone, but may be discouraged so that direct control measures can be effective. A number of different cultural practices, together with the application of a fungicide, can often completely protect a crop from the ravages of a serious disease.

Soil Preparation in Relation to Disease Control

A great many of the troubles of some greenkeepers would be lessened if their putting greens could be rebuilt according to modern improved methods. The unhealthy grass and poor putting surfaces of many putting greens are due entirely to faulty construction. Fre-

quently it is more economical to rebuild such greens than to try to keep the turf alive by chemical treatment or by patching with new sod. When a new green is properly built, maintenance costs may be cut to a minimum, resulting in economy in the end even though the construction costs may have been high. As the construction and rebuilding of putting greens have been discussed in several previous numbers of the Bulletin the subjects will not be treated in detail here.

The physical condition of the soil is one of the most important factors in determining whether or not a putting green will be satisfactory from the standpoint of disease control. For best results, the topsoil of new putting greens should be a sandy loam rich in organic matter. If such a soil is not obtainable, a mixture of sand, clay, and organic matter which will be of good texture can be prepared. The topsoil should be at least from 4 to 6 inches deep.

The chemical condition of the soil is also important in warding off diseases. To give the grass the best possible chance it is well to take the acidity of the soil into consideration, since some of the injuries to turf during hot weather are due directly or indirectly to soil acidity. The soil should be tested, and if the acidity is well below the neutral point it should be treated with lime. On many soils about 50 pounds of hydrated lime to 1,000 square feet will raise the pH value one point. The acidity of the soil of a putting green should be determined from time to time after the turf has developed, so that it can be corrected if it should become unfavorable. The question of proper soil reaction is a complicated one which can not be discussed fully here but which will be discussed in the next number of the Bulletin.

Care should be taken to see that the materials used in the preparation of soils for putting greens contain no injurious substances. Sometimes soil taken from salt marshes or the seashore is used in construction work, and the high concentration of salt is often injurious to grass. There have been cases where manure, charcoal, and other materials used to improve soil have been found to contain injurious salts. Heavy applications of fertilizers may also cause injury from high salt concentration. It is difficult to correct the condition arising from the use of materials containing injurious salts. The chief remedy is leaching, which is a long process.

Addition of organic materials to soil which contain injurious salts aids in lessening the amount of damage caused by them. A good complete fertilizer at double the rate used on putting green turf may be raked into the top layer of soil before planting to correct any chemical deficiency.

Drainage

The satisfactory growth of grass on a putting green depends largely on the ability of the soil to hold enough water to support plant growth and to allow any excess to drain off rapidly. When the soil holds too much water, grass can not be grown successfully, algae become troublesome, and brownpatch and spotblight are much more prevalent and severe, especially in the hot summer weather. Snow-mold and ice injury also are more serious on poorly drained putting greens than on those properly drained. The proper underdrainage of putting greens is important in preventing injury from excess water.

Much of the inadequate drainage found on putting greens is due to faulty construction and the use of poor materials. Wherever pos-

sible, a light soil should be used in construction work. When the subsoil is heavy, underdrainage should be provided. With a heavy subsoil it is advisable also to build a green somewhat higher than the level of the surrounding soil. Great care should be taken also to see that the subsoil foundation of the putting green has no pockets and that water will run off. This is important, because often if the subsoil is heavy these pockets will hold water, and when the topsoil has been applied it will remain saturated for long periods after excessive moisture has drained from the rest of the soil. Turf over such pockets may suffer from poor drainage even though the green has adequate surface drainage. The surface of heavy subsoils should also have

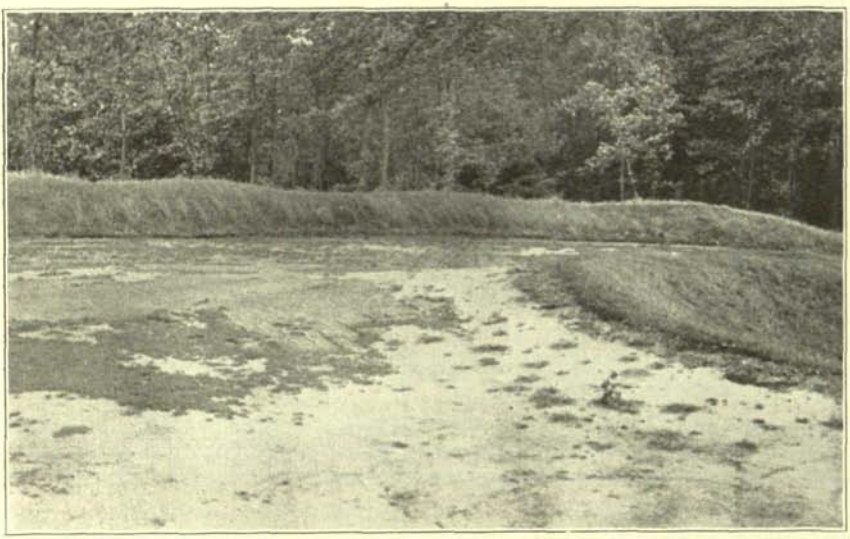

Figure 12.—An example of how injuries to turf may be increased by faulty construction and maintenance methods. This putting green on sandy soil was built up too high from the natural soil level, thus providing too thorough underdrainage. Steep slopes in the green made surface water run off too rapidly, increased the difficulty of watering, and encouraged rapid drying of turf.

a greater grade than the surface of the topsoil that is spread over it. In some cases the underdrainage can be improved by tile drains. Putting greens should be protected from seepage water by tile lines that carry excess water off quickly.

All materials such as soil, sand, clay, peat, and manure used in the topsoil of a green should be thoroughly mixed to prevent the formation of layers. Clay, sand, peat, or manure, in distinct layers in the soil interfere with the capillary rise or fall of water.

The turf should also have surface drainage even when the underdrainage is perfect. When soil is frozen, surface water will not penetrate and is therefore not removed by the underdrainage, so that ice and water from melted snow may collect in pockets where it may result in ice injury.

High knolls and sharp ridges should never be used in a putting surface, for it is difficult to mow them without scalping and to give them sufficient water to keep them from becoming too dry. If the

topsoil is of poor texture and easily becomes puddled or packed even slightly-raised knolls or ridges may shed water and a deficiency of water in these areas may result.

Air Drainage

Injury from brownpatch, spotblight, and other diseases can be reduced on putting greens in certain locations by providing sufficient air drainage. Where a putting green is partially surrounded by trees an air pocket is formed, especially if it is in the lee of prevailing winds. Putting greens situated in ravines also may have insufficient air drainage. Improvement of air drainage in most cases can be provided without removing any trees. Clearing the underbrush or removing a few branches of trees, particularly in the direction of prevailing winds, will often provide sufficient air drainage. In some cases it is possible to cut a lane through the trees at an angle so that the lane can not be seen from the fairway or the front of the green. Such a lane may allow a swirl of air to cross the green. When one is attempting to improve the air drainage on a green he must carefully consider all the possibilities before he ruthlessly removes trees which add to the beauty of the hole and which would be impossible to replace.

Putting greens are difficult to maintain when they are heavily shaded. When putting greens are built among trees they need exceptionally efficient drainage to prevent their becoming water-logged, because they usually dry out very slowly. Often the shade on the green can be reduced by thinning out branches of surrounding trees.

Watering in Relation to Disease Control

The number of courses on which greens have suffered from overwatering has been greatly increased in recent years, and courses on which greens suffer from lack of water are much less common. The tendency to overwater has been due in part to the demands of golfers for soft greens which hold any shots that strike the green. Having the greens too soft removes the necessity for well-played pitch shots and eliminates one of the most interesting phases of the game.

Many greens are constructed of such heavy soil that they become extremely hard when they dry out. Water is applied to soften them, and trampling by the players causes the soil to become puddled and aggravates the condition. More water is then added to soften the green, and a vicious cycle continues until the amount of water added is so great that the roots of the plants are drowned. The deeper roots are the first to die, and if the condition is prolonged it results in a shallow root system which easily dries out during hot periods, and thus the turf on an overwatered green may actually die from lack of water.

A soggy condition of the turf also encourages the development of disease. The fungi which cause disease need abundant moisture for their best growth, and when the soil is kept almost saturated with water they develop profusely and cause severe injury to the turf. During hot, wet summers brownpatch is much more prevalent than during dry seasons. Dollarspot and spotblight are also greatly encouraged by abundant water. When the turf is in a soggy condition diseases may become so serious that even a strong application of fungicide will not check them. The grass becomes tender and may

be burned by an application of a fungicide, so that a heavy treatment can not safely be made. In fact, brownpatch and spotblight can be prevented in a large measure by careful watering. Much less fungicide is necessary to control disease when the greens are kept moderately dry than when watered in excess.

Greens should be watered only when water is necessary. On some courses watering is a routine performed every day whether or not there has been rain recently and whether or not the turf is saturated. The most convenient way to determine the amount of water in the soil is to examine a small plug removed from the putting green with a jackknife. If water can be pressed out of the plug with the fingers several hours after watering, the green has been overwatered. It is better to keep the turf somewhat dry to encourage deep roots and thus avoid a multitude of turf troubles.

Figure 13.—Overwatering of turf is often more disastrous than underwatering. The effects of overwatering first become evident in the low areas as shown in the putting green pictured above. It is well to use extreme caution in watering turf, especially on heavy soils or where the surface drainage or the underdrainage is poor.

There has been much discussion as to the correct time for watering. Experiments have shown that when the greens are overwatered it does not matter when the water is applied, but when the greens are correctly watered much less disease occurs when the water is applied in the early morning. The evening watering wets the top layer of soil which may have become somewhat dry and enables the fungus to become active. The amount of moisture in the soil influences the formation of dew, and evening watering often increases the amount of dew. The presence of excess water in the soil during the night and the formation of heavy dew encourage fungus growth. It is well to allow the grass and soil to be somewhat dry during the night. When water is applied in the morning the droplets of dew are washed from the leaves leaving a thin film of moisture which dries more rapidly than the dew drops. Thus the turf dries more

rapidly than it would have dried had no water been added, which may result in a shortening of the time that the fungus can be active.

Avoid Overfertilization

Care in the use of fertilizers can save a greenkeeper much trouble. In recent years the tendency has been to overfertilize. Sometimes too much fertilizer is worse than not enough. High rates of application, particularly with inorganic fertilizers, cause severe burns which are slow to heal. Rates not heavy enough to directly burn the foliage may still be the primary cause of injury. Grass that is overstimu-

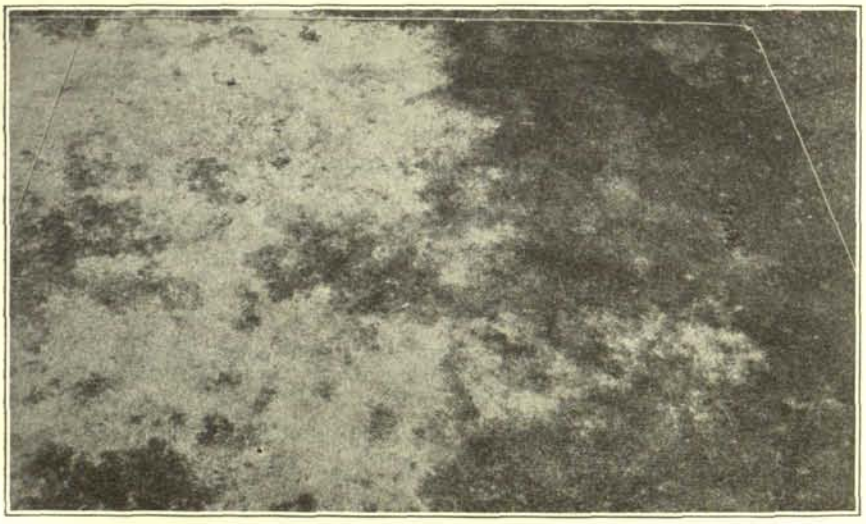

Figure 14.—This piece of turf is suffering from overfeeding. Too much organic fertilizer had been applied. On the right half of the plot the damage is less severe, due probably to the fact that there it had been treated with corrosive sublimate for the control of brownpatch; the chemical probably retarded the decomposition of the fertilizer.

lated becomes tender and succulent, and disease under these conditions is difficult to control with fungicides. Brownpatch, spotblight, and snowmold are particularly injurious to tender turf, which, once injured, recovers slowly when overfertilized.

Overfertilization may cause a number of other undesirable effects from which the turf is slow to recover; injurious substances may accumulate, acid conditions may arise to which the grass may be intolerant, injurious salt concentrations may develop, and root systems may become materially reduced. The growth of algae is encouraged by overfertilization, particularly with organic fertilizers.

The application of large quantities of organic fertilizer in the spring and summer is often dangerous. Such fertilizer may decompose but little during the spring and early summer and may not become available to the grass. When the turf does not respond to the first application of such a fertilizer it is not unusual to find that the application is repeated even two or three times in an effort to give the grass on putting greens an early start. In this manner a large amount of undecomposed organic fertilizer may be accumulated which

during warm wet periods may decompose rapidly and release so much plant food that the grass is killed.

Turf damaged through overfertilization is slow to recover. It is difficult to remove the immediate cause of the injury, and often the only remedy is to resod the damaged areas. Accumulation of many injurious substances can be removed only by leaching with heavy and frequent watering, which in most cases is not advisable, because damage from overfertilization is often aggravated by abundant moisture.

Prevention of these injuries is much more effective than the cure. A fertilizer program should be followed which keeps the turf healthy at all times. The fertilization of turf depends on the natural fertility of the soil, the amount of nutrients lost by leaching, the climate, and the weather. In most cases applications of complete fertilizers should be made in the fall and early spring. During the late spring, summer, and early fall only readily-available nitrogenous fertilizers need be used. Fertilization in the fall and spring encourages root development, and a more vigorous turf results. During the critical summer months, underfertilization is to be preferred even though the turf may become slightly discolored. A putting green in that condition can be put in excellent condition in a few days by small applications of nitrogenous fertilizers; and the putting surface may be kept true even when the grass is growing slowly.

Turf often suffers also from a deficiency of certain elements. In a complete fertilizer, nitrogen, phosphorus, and potash are supplied. Calcium and magnesium are necessary in the soil both as correctives of acidity and as plant food. Both of these are contained in most commercial lime. When a deficiency of iron occurs it may be corrected by the application of iron sulphate at the rate of from 1 to 3 pounds to 1,000 square feet.

Topdressing in Relation to Disease Control

Unsuitable topdressing materials and incorrect methods of application are to blame for much damage to turf through the production of soil layers, turf mats, overfertilization, smothering, or weed infestation. The purposes of topdressing are to keep the turf in a healthy growing condition, to create a true putting surface, and to provide sufficient resiliency for holding a pitched ball.

A desirable topdressing mixture is a sandy loam rich in organic matter, and the character of the mixture should remain constant for long periods. Such a mixture builds up a favorable topsoil, which is beneficial especially where the natural soil is poor.

Topdressings need not be rich in fertilizers since plant food can be applied more economically by direct application of fertilizer. A topdressing often contains a large amount of fertilizer, such as decomposing manure or other materials. This fact is often overlooked in preparing a fertilizing program, and as a result overfertilization may follow.

Care should be taken as regards the origin of materials used in topdressings. They should be tested for acidity and, if found to be too acid, lime may be added. In some cases where peat, sand, or soil is taken from locations along the seacoast the material is apt to contain sufficient salt to injure turf. The material should not be taken

from locations abounding in weeds. Many golf clubs introduce sufficient weeds in topdressing to keep crews of weeders busy all summer.

Changing the type of soil used in successive applications of topdressing has often been the cause of injury. When the mixture is not of a constant type the formation of layers results. These may consist of successive layers of sand, clay, and organic matter. Layers are also formed by burying thick mats of turf with heavy topdressings. Soil layers can sometimes be partially corrected by spiking and topdressing with suitable materials, although frequently it is found necessary to remove the sod entirely and mix the layers.

Figure 15.—Raking a putting green planted with stolons of creeping bent. The tendency of creeping bent to mat under putting green conditions is likely to result in unhealthy turf unless this matting is controlled by occasional raking. Should a thick mat develop through inattention to raking, it should be raked immediately and then cut. The excess leaves and stolons should then be removed, and the putting green topdressed and fertilized.

In some cases topdressing is neglected in the summers, with the result that, particularly with creeping bent turf, a thick mat of grass leaves and stolons is formed. When this occurs the mat should be removed before topdressing is applied. This can be accomplished by thorough brushing or raking followed by close cutting. In case there is only a thin mat of turf, a light brushing and cutting may answer. Brushes on mowers, or stable brooms, are often used for this purpose. Iron rakes with sharpened teeth may be necessary for the thicker mats, which should be successively raked and cut in several directions until the mat is removed. It may be necessary to repeat the process several times before topdressing. To prevent the

occurrence of a thick mat, particularly with creeping bent, turf should be raked and cut each time before it is topdressed; furthermore, it should be topdressed with sufficient frequency.

Sterilizing Soil and Topdressing

Sterilization of soil to kill fungus organisms, and thus to control damping-off and other soil-borne diseases, is used effectively by growers of several important farm crops. The soil is usually sterilized several inches deep before planting the crop. Some plants are injured by toxic substances formed in the soil during the process of sterilization; hence the soil must be exposed to air for several days until these poisonous substances have been eliminated. After the soil organisms have been killed by sterilization, introductions of organisms may occur from outside sources, thus again contaminating the soil. It has therefore been found necessary under this procedure to take measures to protect the sterilized areas from subsequent contamination, throughout the period when the plants are susceptible to these soil-borne diseases.

In only a few cases is it of value to sterilize soil of new seedings for disease control on golf courses because the readiness with which new organisms can be introduced into sterilized soil results in recontamination before the turf has had a chance to become well established. It is of no value in disease control to attempt to sterilize topdressings for use on established turf, due to the fact that the soil to be topdressed is as a rule already contaminated. In instances where sterilization of soil is desirable for controlling damping-off of seedlings on newly planted putting greens, it can be accomplished in the same manner as sterilization of soil to kill weed seeds. This method of weed control is practiced effectively on some golf courses and has been described in previous numbers of the Bulletin.

Height of Cut in Relation to Disease Control

The cutting of putting greens too high or too low has been persistently blamed by many golfers as the chief factor in the prevalence of turf diseases. Experiments have shown, however, that when the height of grass has been kept within the limits permitted on modern putting greens there has been little difference in the amount or severity of brownpatch, spotblight and dollarspot between the low and high-cut grass except where a mat of grass has been permitted to develop. Matted grass which often leads to disease and injury is more likely to develop on long-cut grass, but it may occur on turf cut at any height. Among the bent grasses used on putting greens only in the case of zonate eyespot of Virginia creeping bent has there been distinctly more disease on low-cut turf than on the high-cut. In fairways, however, Kentucky bluegrass and fescue, when cut too low, do not thrive, with the result that leafspot and footrot are more serious than when the grasses are allowed to grow longer.

Sod Nursery

The demand for good turf at all seasons of the year makes it desirable for greenkeepers to have sod available for replacing on short notice any dead areas on their putting greens. Turf injury may occur quite accidentally and unexpectedly, and unless the injured area is resodded it may take months to heal. Every golf course should have a sod nursery of sufficient size to meet the requirements of a bad

season. It is impractical to maintain sod nurseries sufficiently large to replant extensive areas which may be destroyed during exceptionally bad seasons.

The soil for the sod nursery should be prepared similarly to soil for a putting green. If the nursery is planted on heavy clay and the sod from it is placed on a putting green of quite different type of soil, the layer of clay will remain in the soil and perhaps cause trouble later. It is not necessary that the sod in the nursery be kept growing as vigorously as putting green turf, but it should be weeded, cut, watered, and topdressed often enough so that it can quickly be developed into putting condition.

The sod nursery should be planted with grasses similar to those used on the putting greens of the course. The practice of resodding areas with a different kind of grass spoils the appearance of putting greens and should be avoided unless it is definitely planned ultimately to convert the putting greens to that particular kind. Only in those cases where the putting greens have been planted with an undesirable type should the sod nursery be of a different grass.

DISEASE CONTROL WITH FUNGICIDES

Cultural practices influence to a great degree the frequency and severity of diseases. Many nonparasitic diseases can be corrected only by proper cultural practices. These practices, however, can not completely control fungus diseases, but they may, to a great extent, lessen the frequency and severity of the attacks. If, by cultural practices, the amount of disease can be materially diminished, the cost of controlling it with fungicides may be greatly reduced. It should be the aim of every greenkeeper to use those cultural methods which tend to discourage fungus diseases. If he depends on fungicides alone, he not only uses more of them, with consequent greater cost, but he also finds that in extreme cases, which are likely to arise, injured turf dies before he has a chance to treat it.

In selecting a fungicide to use in treating a disease several factors should be considered. These are length of time required to check the disease, length of time turf is protected against subsequent attacks, chance of chemical injury to grass resulting from the treatment, ease of applying the chemical, and the unit cost of the material in relation to the amount that must be applied to obtain the desired results. Fungicides often have advantages and disadvantages which must be weighed one against the other in order that the most desirable one may be selected.

Development of Fungicides

In the seventeenth century, as indicated on page 100, men attempted to check diseases by coating plants with some common materials, usually those distinguished by color or odor. This method was extended to include the many chemicals now used as fungicides.

Practically all of the common fungicides in use today were discovered during the last half of the nineteenth century. Corrosive sublimate was first used as a soil disinfectant about 1864. The discovery of the germicidal value of formaldehyde was made in 1888, and its use for seed treatment began in 1895. The common use of copper sulphate, also the use of lime with copper sulphate, for seed treatments, began in 1873. From 1883 to 1885 the use of Bordeaux mixture for powdery mildew on grapes was developed. The discovery of Bordeaux mixture (lime and copper sulphate), however,