Methods of Golf Turf Disease Control

With the increasing demand for better turf by the golfing public, particularly on putting greens, the greenkeeper is compelled to stimulate an artificial growth of grass with its attendant increase in severity of disease. Each disease has distinct symptoms, and the greenkeeper should learn to know these symptoms in order that he may choose the proper method of control. The aim of plant-disease control is not to cure plants, or parts of plants already diseased, but to prevent the spread of disease to parts or entire plants that are still healthy.

When large numbers of plants of the same species or variety are grown close together the opportunities for the spread of disease from one favorable host plant to another are enhanced. When plants are stimulated by intensive culture and abundant fertilizer they become better mediums for many fungus growths and thus more susceptible to serious damage from diseases. Therefore diseases often occur more frequently and more seriously on good turf than on poor, neglected turf. Intensive culture of plants also tends to increase the danger from several nonparasitic diseases, because some of the daily practices used in maintaining putting green turf may have a harmful cumulative effect on the grass.

The control of turf diseases essentially involves three principles of plant-disease control: the use of disease-resistant grasses, the employment of correct cultural practices, and the judicious use of fungicides.

DISEASE CONTROL WITH RESISTANT VARIETIES

It has been observed for generations that there are different degrees of resistance to disease in many species of plants, but this phase of the subject has only recently been studied extensively. Theophrastus, in 286 B. C., recognized a difference in resistance of grains to rust, but no attempts at artificial selection were made to improve the plants cultivated, such as have been made so successfully in modern times.

There are many degrees of disease resistance in plants. A resistant plant is one which is not attacked by a fungus except under conditions which are unusually favorable to the fungus and unfavorable to the plant. A plant which is never attacked by a fungus, even under favorable conditions, is said to be immune. Varieties of plants have often been considered immune to a disease because no attacks had been observed, but when the plants were grown under conditions more favorable for the attack the disease caused slight damage. Such varieties of plants are considered highly resistant but are not classed as immune.

There are two ways in which disease-resistant plants are obtained; by selection and by breeding. By selection, a search is first made for naturally-resistant individual plants, and propogation is made solely from these, excluding seeds or cuttings from any plants susceptible to the disease. Several seasons may be required to develop a resistant plant. In selecting resistant plants it is important to select not only for resistance but for desirable types. The second way, breeding, consists essentially in creating new varieties by crossing disease-resistant plants with other plants. It often happens that disease-resistant plants are of poor type, and it may be necessary to cross them with

plants susceptible to the disease in order to improve upon the type of the resistant parent.

Disease-Resistant Turf Grasses

There is a wide variation in the resistance to diseases among the different grasses, particularly on the putting greens where the most serious disease problems occur. This variation is found not only among the different species of grasses, but also among the different strains within a single species. Particularly is this true with creeping and velvet bents, some strains of which are resistant to some diseases while susceptible to others. No strain of these bents has thus far been proved to be immune to brownpatch or to dollarspot although many have been found to be highly resistant to these diseases. Disease resistance is influenced largely by cultural practices, site of the green, and age of the turf. These factors vary to such a degree that a strain of grass which is resistant on one putting green may be very susceptible in another location where conditions are more favorable for the development of disease. It is impossible to compare the relative resistance of two grasses on different courses or even on different

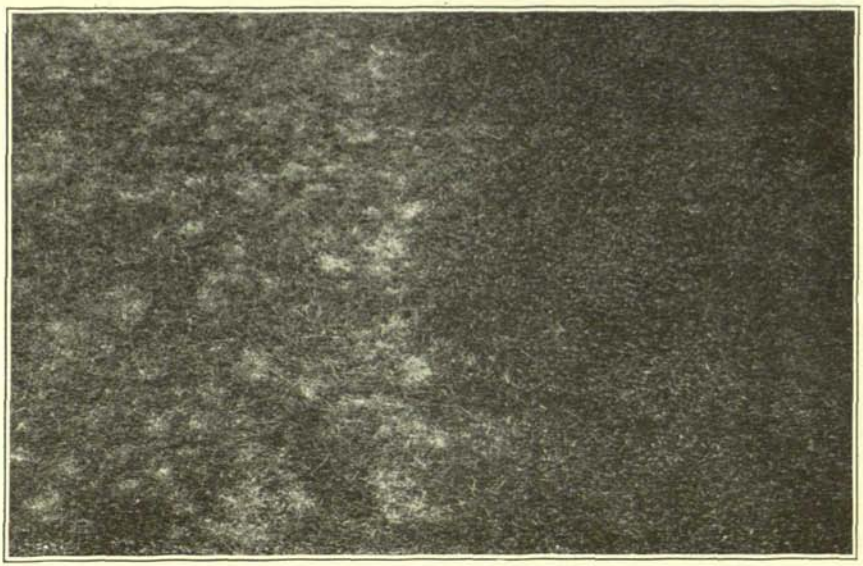

Figure 10.—Difference in resistance of strains of creeping bent to dollarspot. On the right is the Metropolitan strain, which is highly resistant, and at the time the photograph was taken it was entirely free from the disease. On the left, immediately adjoining, is the very susceptible strain of Columbia creeping bent. Both plots were planted at the same time and grew under identical soil and cultural conditions. The economy in the use of resistant strains is obvious.

putting greens on the same course. Only when grasses of the same age are grown side by side and given the same treatment can comparisons of relative resistance be made.

Brownpatch occurs with widely-varying severity on the different strains of creeping bent. Washington creeping bent is much more resistant to brownpatch than is Metropolitan; seaside creeping bent is moderately resistant; and colonial bent is very susceptible to it.

The different strains of velvet bent have varying degrees of susceptibility. The disease in the early stages seems to cause little damage to velvet bents and, if treated, the damaged turf recovers quickly.

Dollarspot attacks Metropolitan creeping bent, colonial bent, and some strains of velvet bent less frequently than Washington, seaside, and some other strains of creeping and velvet bents which are found to be rather susceptible to it.

Spotblight occurs most frequently on Columbia creeping bent, colonial bent, and some strains of velvet bent, and fescue, when the conditions of moisture and temperature are favorable. Severe attacks have occurred on more-resistant strains of creeping bent when conditions have been unusually favorable for disease development.

Snowmold occurs infrequently on Metropolitan creeping bent, some strains of velvet bent, and colonial bent. It occurs frequently on Washington and Virginia creeping bents but usually not severely.

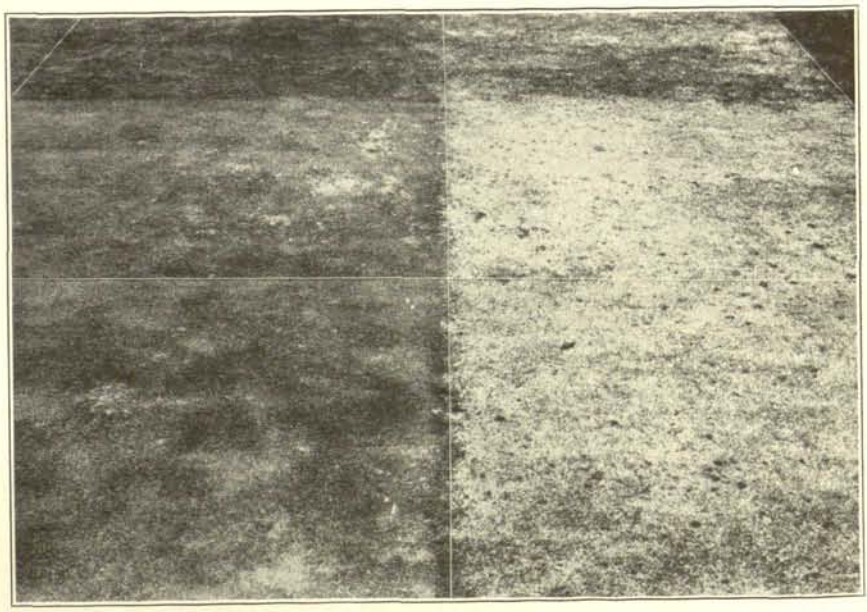

Figure 11.—The difference in disease resistance among strains of grasses is sometimes remarkable. Here Washington creeping bent (left) and Virginia creeping bent (right) are growing side by side. The latter is ruined by zonate eyespot, a disease to which the former shows marked resistance. The turf in the background is not cut as close as that in the foreground and the disease is not causing as much damage on the long grass. The scattered injury to the grass on the left was caused chiefly by dollarspot.

Columbia and seaside creeping bents, and fescue are the most susceptible to it.

The zonate eyespot is most virulent on Virginia creeping bent. It occurs on other turf grasses in such slight attacks that they generally escape notice.

The growing conditions of the plant determine in a large measure its resistance to disease. Even an exceptionally resistant species or strain of bent may become susceptible under certain cultural prac-

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

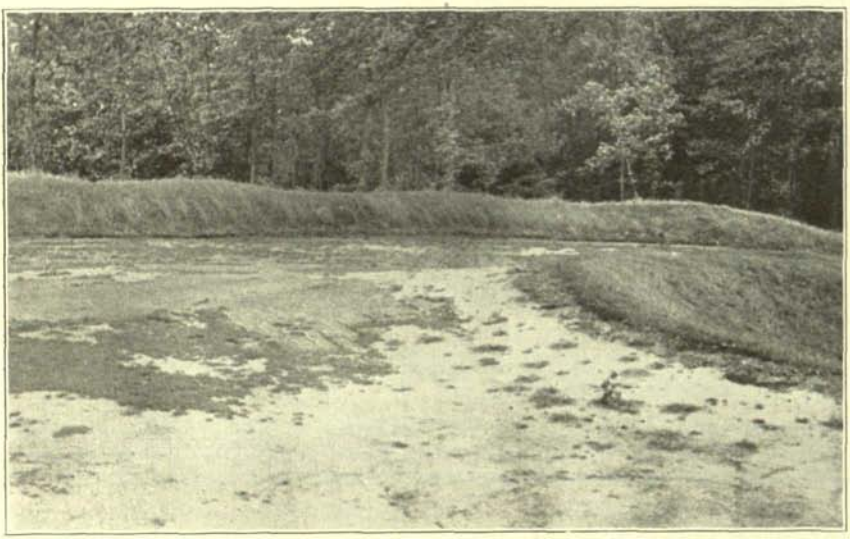

Figure 12.—An example of how injuries to turf may be increased by faulty construction and maintenance methods. This putting green on sandy soil was built up too high from the natural soil level, thus providing too thorough underdrainage. Steep slopes in the green made surface water run off too rapidly,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

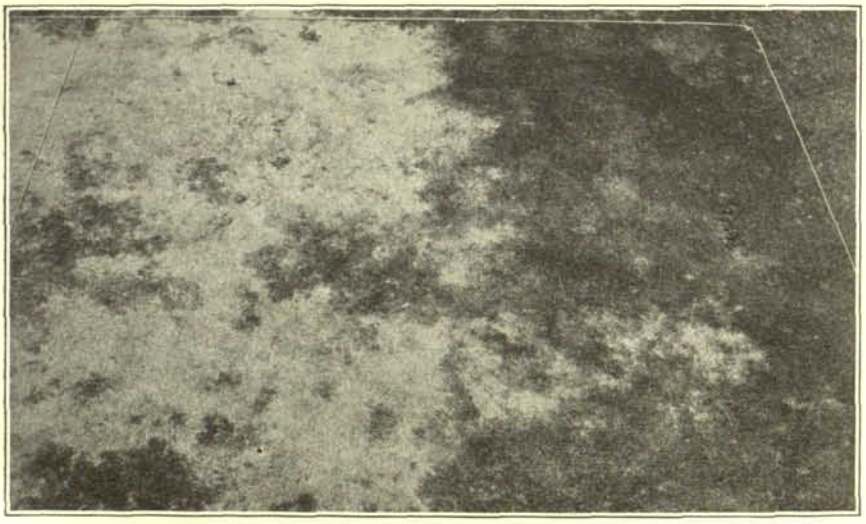

Figure 14.—This piece of turf is suffering from overfeeding. Too much organic fertilizer had been applied. On the right half of the plot the damage is less severe, due probably to the fact that there it had been treated with corrosive sublimate for the control of brownpatch; the chemical probably retarded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

was accidental. It became the practice in some vineyards around Bordeaux, France, to sprinkle lime and bluestone (copper sulphate) on the outer rows of vines to give the fruit a poisoned appearance for guarding against pilfering by passers-by. These outer rows of vines were found to suffer very little, or not at all, from powdery mildew, and the beneficial effect was ascribed to the lime and bluestone, with the subsequent development of one of our most important fungicides.

During the twentieth century most of the work on the prevention and control of diseases has taken place. As each disease became a serious problem it was studied with respect to control measures. The development of definite methods and rates of applications of Bordeaux

Figure 16.—Dusting a putting green in 1922 with Bordeaux mixture for disease control. This was the first fungicide in general use for controlling turf diseases on golf courses. The fungicidal properties of Bordeaux mixture are due to copper sulphate, which had been used as a fungicide for over a century before being brought into use on golf courses.

mixture, copper sulphate, sulphur, lime-sulphur, formaldehyde, mercury compounds, and other fungicides was made during this period.

A Variety of Fungicidal Remedies Are Now Available

In the later development of plant-disease control, chemicals effective as fungicides have become increasingly important in checking injury to plants. These are used for disinfecting soil and seeds and for spraying or dusting the whole plant. Soil disinfection is usually accomplished by dry heat, steam, or fungicides, the most common of the fungicides being formaldehyde, sulphur, and mercury compounds. Seeds and tubers may be disinfected with solutions of formaldehyde, corrosive sublimate or other mercury compounds, or powders such as copper carbonate, copper sulphate and lime, and mercury compounds. Fumes of sulphur and formaldehyde are also used for dis-

infecting seeds and tubers. Hot water or dry heat is also sometimes effective. The purpose of soil and seed disinfection is to kill the disease organisms present in the soil or in the outer coats of the seed. Treatments with sprays and dusts are for the purpose of protecting the uninjured parts of the plants. The most important sprays are Bordeaux mixture and lime-sulphur. For dusting purposes, copper and sulphur preparations are commonly used.

Development of the Use of Fungicides in Turf-Disease Control

In 1917 experiments were first made on golf courses to test Bordeaux mixture as a fungicide for the control of brownpatch. By 1919 its use was general on courses on which the disease was serious. Corrosive sublimate was used successfully as early as 1920 in the Chicago district. The disadvantages of Bordeaux mixture led to the testing of other fungicides in brownpatch control. In 1923 careful study of turf diseases and the organisms causing them was begun by the Green Section, in the laboratory and in the field, and the results of this work have been published in the Bulletin from time to time. Many chemicals are useful as fungicides, but it is not a simple matter to find one that will kill fungi and at the same time not injure the plant on which it is used. A great many chemicals have been tested at the Arlington turf garden for the control of turf diseases.

The following is a list of the fungicides tested at the Arlington turf garden in 1925. The numbers preceding the names in this list are the plot numbers on which the respective fungicides were used, as shown in figure 17.

1. Semesan	1 pound	to 1,000	square feet
2. Formalin	1 quart	to 3,000	square feet
3. Sulphur	4 pounds	to 3,000	square feet
5. Copper sulphate	1 pound	to 3,000	square feet
6. Mercuric chloride	1 pound	to 3,000	square feet
7. Uspulun	1 pound	to 3,000	square feet
9. Corona 620	1 pound	to 1,000	square feet
10. Corona 640	1 pound	to 1,000	square feet
12. Germisan	1 pound	to 1,000	square feet
13. Corona 640	1 pound	to 1,000	square feet
14. Corona 640	1 pound	to 3,000	square feet
15. Uspulun	1 pound	to 1,000	square feet
17. Bordeaux	1 pound	to 1,000	square feet
18. Copper stearate	1 pound	to 1,000	square feet

This illustration shows a row in which there were several plots of the same strain of grass. Plots 4 feet square were treated in a row. The numbers appearing on the several plots in the illustration correspond to the numbers of the respective treatments in the foregoing list. The treatments were sprayed, except in the case of copper stearate, which was applied as a fine dust. The light spots in the photograph are dollarspot and the dark areas are healthy turf where the disease was controlled by the treatments. The treatments in plots 12 and 14 did not overlap and the disease was active in the strip between the two plots. The copper compounds (plots 5, 17, and 18), proved ineffective in controlling the disease. Sulphur and formalin appeared also valueless. Only on those plots which were treated with mercury fungicides—Semesan and Uspulun (chlorophenol mercurials), Corona 620 and 640, and mercuric chloride (corrosive sublimate)—was the disease effectively checked.

The lower cost of mercuric chloride (corrosive sublimate) as compared with the other mercury compounds tested in 1925 induced

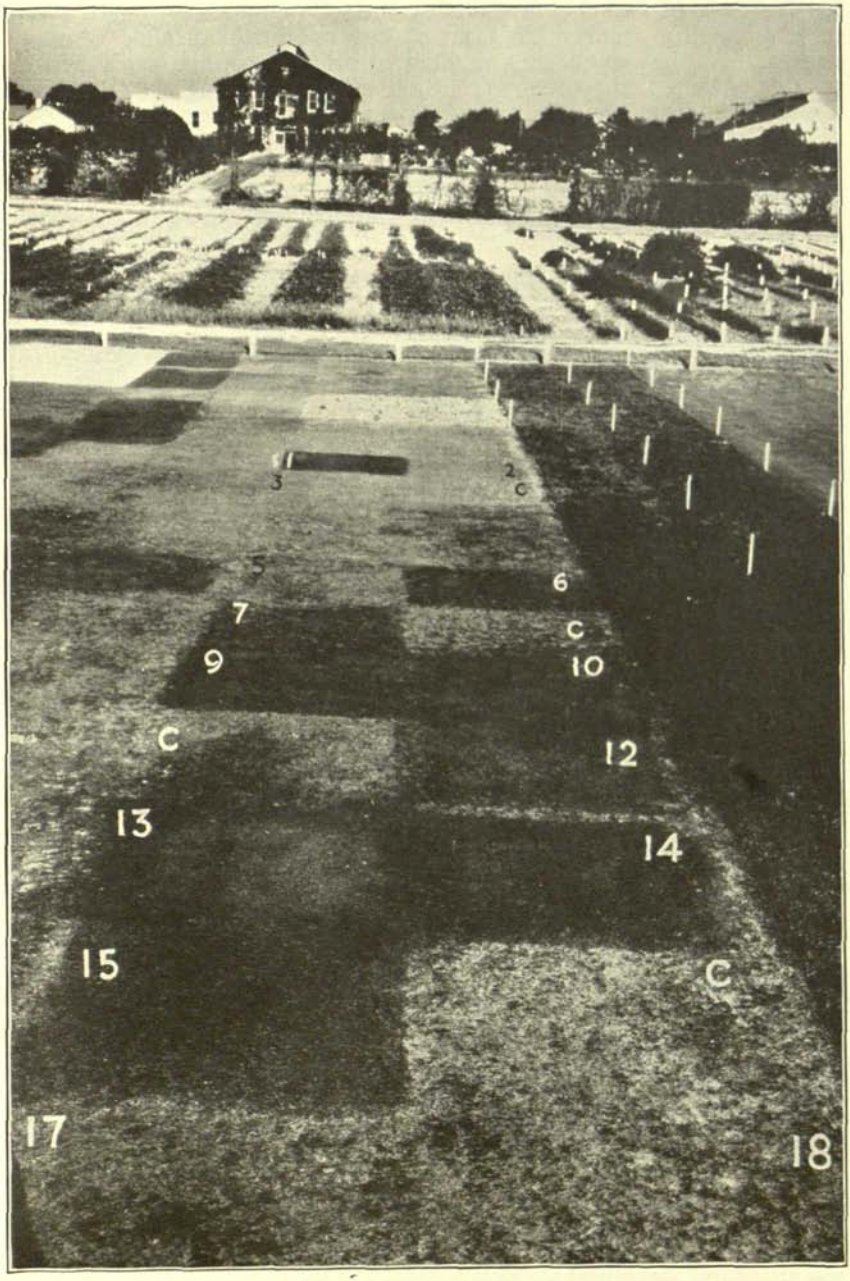

Figure 17.—Comparative tests of 14 different fungicides in the control of dollar-spot at Arlington turf garden. The number on a plot indicates the fungicide used on the plot as listed in the table on the opposite page. The plots marked C are check plots and received no treatment. Light-colored areas indicate damage by the disease.

further tests of this chemical during the following season, with a view to establishing clearly the advantages or disadvantages it might possess. At the same time a number of other inorganic mercury compounds were tested to determine their effectiveness against disease in hopes of finding one which would prove effective for longer periods with less chance of injuring the turf.

In 1927 these tests were repeated. The chemicals used in the experiment, the percentage of mercury in each, and the number of pounds required to carry 1 pound of mercury are shown in the following table.

Chemical	Percentage of mercury	Pounds required to carry 1 lb. mercury
Mercuric oxide	92.61	1.08
Mercuric sulphide	86.22	1.16
Mercurous chloride (calomel)	84.98	1.18
Mercuric cyanide	79.41	1.26
Mercuric chloride (corrosive sublimate)	73.88	1.35
Mercurous nitrate	71.48	1.40
Mercuric sulphate	67.62	1.48
Semesan	16.50	6.06
Uspulun	16.50	6.06

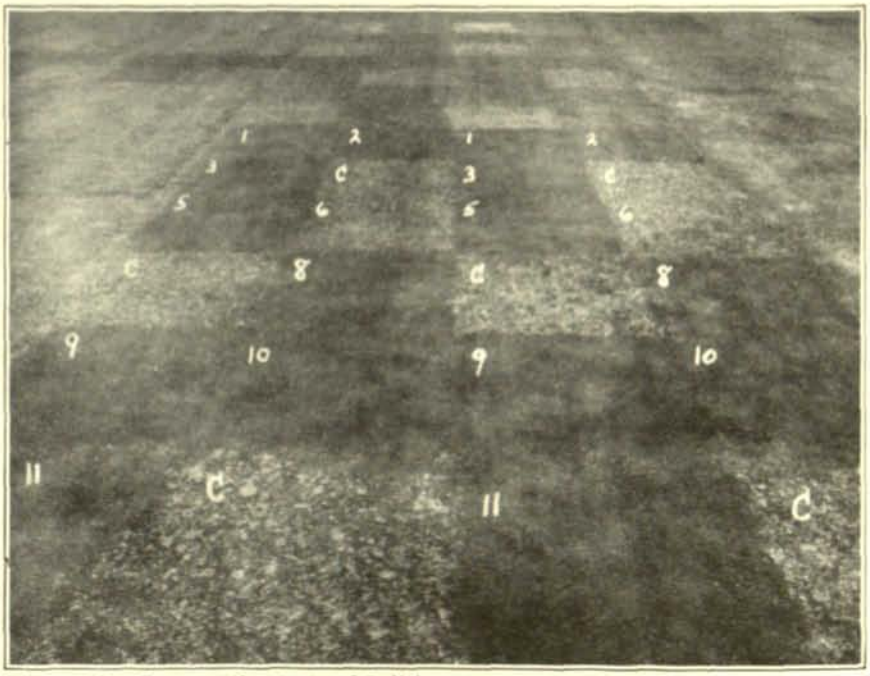

Figure 18.—Comparative tests of 9 different mercury compounds in the control of dollarspot at Arlington turf garden. Each treated plot (16 square feet) received the same amount of mercury (see table in text). This illustrates the similar effect obtained from the different chemicals with the exception of the sulphide. The spotted check plots, which received no fungicides, show how generally the disease was distributed throughout the area tested. The series at the left was on Metropolitan creeping bent; that on the right was on Washington creeping bent. Plot No. 1 received corrosive sublimate. Plot No. 2 received mercuric sulphate. Plot No. 3 received Semesan. Plot No. 5 received calomel. Plot No. 6 received mercuric sulphide. Plot No. 8 received mercurous nitrate. Plot No. 9 received mercuric oxide. Plot No. 10 received Uspulun. Plot No. 11 received mercuric cyanide. C represents check plots, no fungicides.

The rates at which the chemicals were applied were such that each plot received the same amount of mercury. The column at the right shows the number of pounds of the chemical needed for a green of 6,000 square feet if one is to apply 1 pound of mercury. Figure 18 shows treatments on four-foot squares of Washington and Metropolitan creeping bents at the Arlington turf garden. The spotted appearance of the check plots severely injured by dollarspot, when contrasted with the dark squares of healthy turf, shows that all the mercury compounds were effective with the exception of mercuric sulphide (No. 6).

It was found that while all of the chemicals were effective in con-

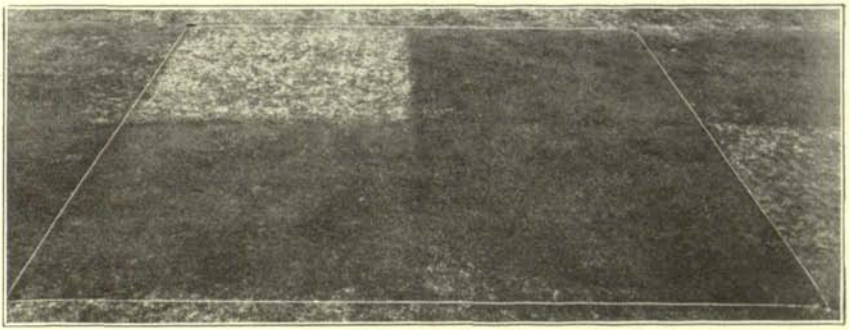

Figure 19.—Control of dollarspot on Metropolitan bent at Arlington turf garden. Of the four plots within the white lines, the lower left was treated with metallic mercury carried in chalk, the lower right with mercuric oxide, the upper right with calomel, and the upper left, reserved as a check plot, received only powdered chalk. The control is complete except in the check plot.

trolling the disease there were slight differences in the rapidity with which the disease was checked, in the length of time that a recurrence of the disease was prevented, and in the danger of burning the turf.

In some tests made later in the summer metallic mercury was applied on plots using the same amount of mercury as in the foregoing series of tests. Mercury in this form was as effective in controlling the disease as in the compound forms, indicating that when considering fungicides for dollarspot the mercury content is the important factor. Figure 19 shows four plots, one of which was treated with metallic mercury carried in powdered chalk, two of which were treated with inorganic mercury compounds, and one of which was untreated.

Fungicides of the Copper Group

Copper Sulphate, bluestone.—This is a common fungicide used mainly for seed treatments. It has been used on golf courses to control algae on greens. It also checks the growth of algae in lakes, ponds, or water hazards where it may be added at the rate of 1 pound to one million gallons of water.

Bordeaux Mixture, copper sulphate and lime.—Experiments with Bordeaux mixture and other copper compounds led to injuries which were far worse than the disease they were intended to cure. This injury was copper poisoning, resulting from the accumulation of copper in the soil; it is likely to develop more rapidly in some soils

than in others. Some of the golf courses which had used Bordeaux mixture for several years were forced to rebuild some of their putting greens to eliminate the soil containing copper. Another disadvantage of Bordeaux mixture was that it would not control dollarspot.

Bordeaux mixture proved effective in controlling brownpatch only when the leaves and stolons of the grass were covered with a protective covering of the fungicide. Therefore it was necessary to treat the greens after each rain or after each watering, which required daily treatments in many cases. It was used as a spray or dust to cover the leaves and stolons with a thin film. The rate of applica-

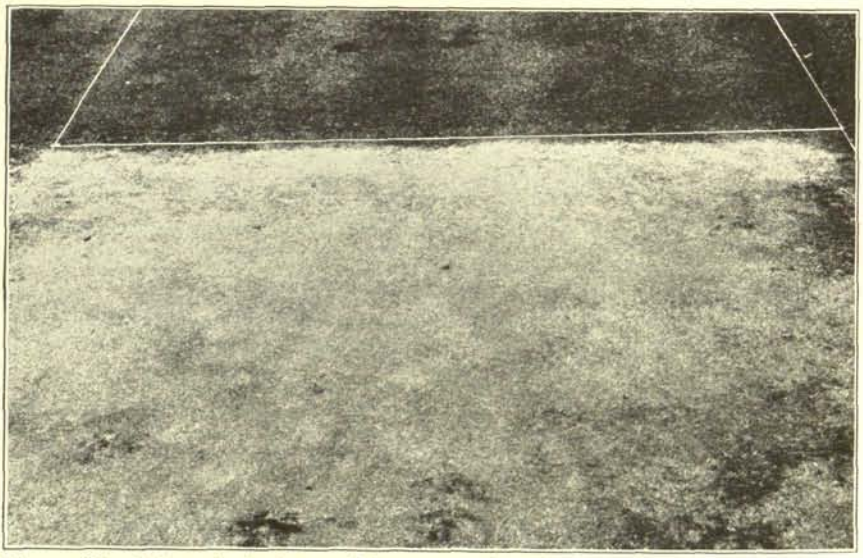

Figure 20.—Injury to turf caused by repeated applications of Bordeaux mixture used to control brownpatch. The light injured turf in the plot in the foreground is a result of accumulation of copper in the soil. The adjoining plot in the background where the turf is a dark healthy green received similar care except that no copper compounds had been used on it.

tion was about 1 pound to 1,000 square feet of turf. The frequency with which Bordeaux mixture had to be applied led to experiments with copper stearate in the hope that the latter would be found to adhere to the leaves for longer periods.

The use of Bordeaux mixture and other copper fungicides was discontinued after the development of the mercury fungicides, which are more effective and which do not leave any injurious residue in the soil.

Fungicides of the Mercury Group

The fungicides most widely used on golf courses are those containing mercury in combination with other chemicals. Mercury in the pure form is a familiar liquid metal which is commonly called quicksilver. This metal combines readily with many other chemicals to form numerous compounds which are widely used in medicine and in commerce. As has been previously explained, either metallic mercury or many of its compounds are effective in controlling certain turf diseases. The effectiveness of these fungicides is largely in proportion to the actual mercury content of the materials applied.

The chemicals with which mercury is combined may be organic or inorganic. The organic chemicals were formerly believed to be products of living organisms but later it was found that they could be manufactured without the aid of living matter. Since that discovery many organic chemicals have been manufactured but the term organic has been retained for them. When mercury is combined with an organic acid it is termed an organic mercury compound. When it is combined with an inorganic acid it is termed an inorganic mercury compound.

Corrosive sublimate (bichloride of mercury) and calomel (chloride of mercury) both are combinations of mercury and chlorine. Corrosive sublimate is formed when mercury in the form of vapor is brought in contact with an excess of chlorine, and calomel is formed when mercury vapor is brought in contact with a small amount of chlorine. When the corrosive sublimate is formed, twice as much chlorine combines with the mercury as when calomel is formed, and for that reason the former is called bichloride of mercury.

Other mercury compounds which are formed when mercury is combined with various chemicals differ in their characteristics of solubility and chemical stability, which characteristics are not limited to either organic or inorganic mercurials. Some of the organic mercurials may be soluble and chemically stable and others insoluble and unstable, and the same is true of the inorganic mercurials.

When mercury compounds, both organic and inorganic, are applied to the soil it is probable that both forms react with the organic acids which are present in the soil and may become very similar in their chemical composition. These reactions are carried on until the mercury in the soil becomes inert and has no further fungicidal effect. This tendency to change in the soil probably accounts for the similar behavior as fungicides of most of the mercurials, both organic and inorganic, when applied at comparable rates. This was explained above in the tests for effectiveness against disease.

Since the active constituent of mercury fungicides is the mercury contained in them it is natural that in general the greater the percentage of mercury the greater will be the effectiveness of the fungicide. Corrosive sublimate and calomel contain 74 per cent and 85 per cent of mercury, respectively. The organic mercury compounds contain smaller percentages of mercury and are usually mixed with some inert material. This further lowers the percentage of mercury in the preparation so that the cost of the mercury becomes excessive.

Mercury fungicides should be bought on a mercury basis. If one pound of corrosive sublimate, containing 74 per cent of mercury, costs $1.00, one pound of mercury in that form costs $1.35. At that price the mercury in one pound of fungicide containing 10 per cent of mercury would be worth 13½ cents.

Comparison of common golf course fungicides at present market prices shows that the actual cost of a single normal application based on the mercury content of the fungicide for 18 average-sized putting greens varies from $20 to $290.

The mercury fungicides which are marketed in pure form for golf course use are corrosive sublimate and calomel. The latter is sold by one manufacturer under the trade name of Calogreen. Combinations of corrosive sublimate and calomel are sold under the two trade names Calo-clor and Pfizer Mixture. Fungicides which are

mixtures of mercury compounds and some inert material which has no fungicidal value include Semesan, Nugreen, Turfcalomel, Barbak 211, Barbak XX, and Fungo.

Corrosive Sublimate, bichloride of mercury or mercuric chloride. —This is used extensively as a disinfectant in medicine. It also is used for treating tubers to control potato diseases, for seed treatment in a few of the cereal diseases, and for soil treatments in hot beds and greenhouses. Corrosive sublimate has been used extensively on golf courses both as a fungicide and as a vermicide. It was the first mercury compound reported to control brownpatch and its use as a vermicide was general before it was used as a fungicide.

This fungicide has been found to be the most quickly effective of the mercurials in checking active attacks of dollarspot and brownpatch when applied at rates containing equal amounts of mercury. A smaller quantity of this fungicide is necessary to check active attacks of these diseases than of any other mercury fungicide. The chief advantage is its rapidity of action, which is especially important in treating brownpatch. In severe attacks corrosive sublimate is the most effective of all mercury compounds. The period of prevention of corrosive sublimate is somewhat shorter than with other mercury fungicides.

Corrosive sublimate causes discoloration to turf when applied at high rates. Its tendency to burn, however, is somewhat greater than is the case with other mercury fungicides when all are applied at rates of relative strength. When conditions are favorable for brownpatch the grass is susceptible to burning, and any mercury compound which checks the disease effectively may cause some discoloration.

Corrosive sublimate is completely soluble in the dilutions used for spraying putting greens, but difficulty is sometimes experienced in preparing the solution. This difficulty can be eliminated by adding common salt to the solution. This matter is discussed in methods of application on page 130.

Calomel, mercurous chloride.—This is used extensively in medicine as a purgative and as a stimulant for the secretory organs. As a fungicide it was first generally used for dollarspot control, but it has recently been used also as a fungicide for controlling potato and other crop diseases. Calomel still is the best fungicide for treating dollarspot. It protects the turf from attacks of the fungus for a longer period than any other chemical when applied at rates containing an equal amount of mercury. This increased period of protection is sufficiently long to make it an important point in favor of calomel. It checks an active attack of dollarspot almost as rapidly as any of the mercury fungicides. It is effective as a lasting preventive for brownpatch. Since its action is slower than that of corrosive sublimate, in some cases it does not check an active attack of brownpatch as quickly as is necessary. Calomel also prevents attacks of snowmold. When calomel is used in combination with corrosive sublimate its adaptability for turf-disease control is extended, as will be discussed later.

Calomel causes less burn than other mercury fungicides when applied at comparable rates. The discoloration of turf caused by a uniform application of the fungicide at a high rate usually appears about 3 or 4 days after application has been made. Ordinarily this does not cause any damage other than to give the turf a yellowish

or browned appearance. When the chemical is not applied evenly serious burns may result which may take a long time to heal. Since lumps of calomel are likely to cause burns it is necessary to take precautions that the chemical to be applied contains no lumps. Calomel is insoluble, and even when finely ground it quickly settles in water because of its extreme weight. Therefore if it is to be applied either by sprinkling or by spraying, the water should be kept thoroughly agitated while making the application.

Combinations of Corrosive Sublimate and Calomel.—Since corrosive sublimate and calomel each had advantages not possessed by the other, it was apparent that a combination of the two could be used to advantage. This was particularly true for brownpatch. Dollarspot can be effectively controlled with calomel alone, but in the Arlington experiments active brownpatch was not immediately checked. Combinations of 1/3 corrosive sublimate and 2/3 calomel proved effective for brownpatch. For extremely active cases of the disease 1/2 corrosive sublimate and 1/2 calomel has been more effective. This treatment has advantages in that it checks the disease immediately, due to the corrosive sublimate, and gives a long period of control due to the calomel. Combinations of the two chemicals in various other proportions have also proved effective.

Such combinations were first suggested by the Green Section in the Bulletin in 1927 and since that time preparations containing mixtures of corrosive sublimate and calomel have appeared on the market with trade names.

Mercuric Oxide.—Another inorganic mercury compound that has been tested is mercuric oxide, both yellow and red. This is rated between corrosive sublimate and calomel as to effectiveness and as to injury to turf from overdoses. It checks brownpatch more quickly than calomel, but not as quickly as corrosive sublimate. Like calomel, it is insoluble in water, but it remains in suspension better than calomel. Its period of protection is not as long as that of calomel but considerably longer than that of corrosive sublimate. It does not burn the grass as severely as corrosive sublimate but more severely than calomel. Mercuric oxide has not been used to any great extent on golf courses, but may be used to advantage in some cases.

Organic Mercury.—Several organic mercury compounds have been included among the mercury fungicides tested for their effectiveness against turf diseases. One of the first of these to be used extensively on golf courses was chlorophenol mercury, the active constituent of Semesan and Uspulun. The organic mercury compounds have been effective in controlling brownpatch and dollarspot but have not exhibited any greater value as turf fungicides than mercury in the inorganic form. The organic compounds do not check brownpatch as quickly as does corrosive sublimate, but more quickly than calomel. They also are rated between those two chemicals in their burning effect on grass. Since those in golf course use are soluble they are preferred by many greenkeepers who have power sprayers which are equipped with agitators insufficient to keep calomel in suspension. The manufacturing cost of organic mercury compounds is usually greater than that of the inorganic compounds and therefore the sale prices are higher. Treatment with these organic mercurials is more expensive than with the common inorganic compounds, since it requires from five to ten times as much of them to obtain results com-

parable with the inorganic mercury fungicides. This is due to the fact that the organic fungicides contain inert materials and the mercury content is from 1/5 to 1/10 the quantity that is contained in the inorganic compounds.

Fertilizer-Fungicide Combinations.—Fertilizers are sometimes combined with mercury fungicides and sold under trade names for the control of turf diseases. The main disadvantage of such combinations is that too high prices are usually paid for the fertilizer they contain. Another disadvantage is that the recommended rates are often so small that the fungicide must be applied more often than is necessary with other types of fungicides. This greatly increases the cost of labor.

Miscellaneous Fungicides

Other fungicides which have been tested for golf turf diseases include formaldehyde, sulphur, various zinc compounds, silver nitrate, and potassium permanganate. None of these has proved to be of practical value. Silver nitrate controls dollarspot as effectively as the mercury compounds but its high cost makes it prohibitive. In preliminary tests formaldehyde showed slight control of brownpatch but subsequent tests showed that it had no practical value because of its extreme toxicity to grass. Various forms of sulphur have proved valueless as a turf fungicide and are toxic to grass. Sulphur apparently makes grass even more susceptible to dollarspot, due either to the greater acidity produced or to some effect that the sulphur has on the plant.

Rates of Application of Fungicides

The rate at which the mercury compounds should be used for turf diseases depends upon the season, the condition of the grass, the weather, and the amount of fungicide that has previously been used. Some greenkeepers treat all their greens at regular intervals whether or not disease occurs; others treat only when they notice an attack. The decision depends upon the amount of disease that ordinarily occurs. If in the experience of the greenkeeper disease occurs continually throughout the season as it does in the more southerly districts of the northern grass belt, then it is best to treat at regular intervals. On some of the northern courses, where the disease occurs only occasionally it is more economical to treat only when the disease occurs. The frequency of treatment also depends on the season. During dry seasons there is likely to be less disease and therefore fewer treatments will be necessary.

Early or late in the growing season the grass is not so tender and larger amounts of the fungicide can be used safely. A safe rate at that time is 3 ounces of corrosive sublimate or calomel or a combination of the two or of mercuric oxide, to 1,000 square feet. One pound or more of organic mercurial also can be used at this time, and this amount is necessary to give the same effect as the smaller amounts of inorganic chemicals. When the weather gets warm in the middle of the summer the grass is more easily burned and smaller rates must be used. It is necessary then to use 2 ounces of the inorganic mercury compounds or 2/3 pound of the organic. If it is extremely hot and humid and the grass is tender then the rate must be cut down to 1½ ounces or even 1 ounce of the inorganic and a relatively-decreased amount of the organic.

There is a cumulative effect from mercury compounds in the soil. The first treatments of the year are not likely to be as effective as the later treatments. When the turf has been treated year after year less mercury is required to check the disease than on turf where no treatments have ever been applied. This cumulative effect applies also to the chance of injury to turf due to chemical burn. Where much mercury has been used the grass is burned by smaller amounts than where no mercury has been used previously. The first treatments therefore can safely be much stronger than the subsequent treatments particularly if the turf is treated at regular intervals. New turf can stand stronger treatments than older turf which has been regularly treated.

APPLYING FUNGICIDES

Several methods for applying fungicides to turf are available for golf courses. The method that is used varies with the preference of the greenkeeper and the available equipment. A method may be practicable on one course and impracticable on another course because the equipment and trained help vary considerably on different courses. The method used will also depend on the frequency with which the disease occurs and the amount of turf that must be treated, since it is important to apply fungicides promptly after an attack of fungi is noticed, so that the disease may be checked quickly and the severity of the injury lessened. The method to use is that which will give the most even distribution in the shortest time and at the least cost.

The fungicides usually used on golf courses are mercury compounds which, if carelessly applied, cause injuries to turf that may be more serious than the diseases for which they are applied. The small amounts of the fungicides necessary to cover large areas make it difficult to distribute them evenly. It is usually desirable to dilute them to give greater bulk, for only rarely is it possible to apply a fungicide to golf course turf without dilution. Any of the chemicals effective in the control of turf diseases may be applied either in water or mixed with sand, soil, or other material.

It is essential to obtain even distribution regardless of whether the fungicide is applied in water or in a dry state. Uneven distribution may result in chemical burns on those areas which obtain an excess of the material and ineffectiveness of the treatment on those areas which do not receive an adequate amount of the fungicide. To assure even distribution of the material to be applied it is advisable to make the application in two parts. The first part is applied by starting at one side of the putting green and walking back and forth in parallel lines far enough apart so that the application does not overlap or that no part of the turf is missed. Great care should be taken that the treatments do not overlap since bad burns may result where overlapping occurs. After the first half of the material has been applied the second half is applied by walking back and forth in parallel lines which are at right angles to the direction of the first treatment. Treatment thus made in two directions greatly increases the uniformity of the distribution. This method is often used in seeding to assure even stands of plants, and it is useful whether the treatment is made dry in sand, soil, compost, or dry fertilizer or in liquid from sprayers, sprinklers, or proportioning machines.

The turf should be watered thoroughly immediately after the

application of a fungicide, except where it is desired to leave the fungicide on the blades of grass, as is the case when very small amounts of corrosive sublimate are applied. The laborers must be trained to water correctly. If the greenkeeper is not watchful, the laborer will wash the fungicide from the elevations to the low areas of the putting green by careless watering. In consequence, the elevations will be subject to reinfestation by disease while the low areas will be liable to suffer from burns due to the concentration of the fungicide. The men should be allowed to water only with nozzles that create a fine spray or mist, and should be instructed to hold the nozzles up so the spray may lose its force before striking the turf.

When excessive amounts of fungicide have been applied to turf either by high rates of application, heavy doses from uneven distribution, or by spilling of concentrated solution or dry materials, the grass should be watered immediately and abundantly. In cases when the fungicidal material has been spilled or applied heavily on small areas the watering should be concentrated on the affected areas so that the chemical will be washed into the soil.

After an application of fungicides is made, whether it is by the dry method or liquid method, it should be watched for burning. When the turf appears to be burned from an application of fungicide it should be watered again immediately. If the watering is liberal much of the injury from burning will be eliminated. Fungicidal treatments should not be applied to turf and then be forgotten.

One often finds that laborers are apt to give double doses of fungicides to diseased areas unless warned. This may occur either with spray or dry methods of application. It is not uncommon to see a spray operator pause to spray more thoroughly a diseased area, or a man spreading by hand throw a few extra handfuls on the diseased areas. This concentration on the diseased turf usually results in bad burns and perhaps kills much turf that ordinarily would have recovered. The men applying fungicides should be told that the treatment, when made over large areas, is to prevent spread of the disease to healthy turf and that therefore the fungicide must be applied evenly, regardless of diseased or healthy parts.

In handling any of the mercury fungicides care should be taken that the chemicals are not scattered about so that there is any danger that they will become mixed with food of animals or human beings because they are extremely poisonous. If any of the mercury compounds are accidentally swallowed, a physician should be called immediately. Vomiting should be forced by giving soapsuds or salt in warm water, followed with white of egg or milk of magnesia. There is a possibility that when even small amounts of mercury are absorbed into the body at different times, an accumulation of the metal occurs in the system, which may be injurious at some later time. To guard against this danger it is advisable to wear a wet cloth or other filtering mask over the nose and mouth when preparing mixtures of these compounds and when applying them to the turf.

Some mercury compounds have a corrosive action on metals. All metal equipment should be washed thoroughly after having come in contact with these chemicals. Corrosive chemicals should always be kept in wooden, glass, or earthenware containers and should not be handled with metal spoons or paddles. They should not be weighed on metal pans of scales unless the metal is protected by paper or other non-corroding materials. Dry mixtures of these fungicides should

be kept in wooden containers, when stored even for short periods. Sprayers and other equipment used for mixing and applying liquid treatments should be washed after use to prevent corrosion. Hose connections should be examined from time to time to determine whether or not they have been weakened by corrosion. Severe burns have resulted on greens where hose connections have broken and large quantities of fungicides have spilled on the turf.

Dry Methods of Application

Many greenkeepers prefer to apply fungicides in the dry state. This method has an advantage over the spray method in that it does not require a large outlay for expensive equipment, nor is there heavy equipment to haul over the golf course. Some greenkeepers find that they can treat their putting greens more quickly by the dry method than by the liquid method.

Fungicides have been applied in the dry state by dusting them on the turf. This method was used when Bordeaux mixture was applied to turf to control brownpatch. Since treatment with Bordeaux mixture has been discontinued the practice of dusting has fallen into disuse on golf courses. With the mercury fungicides it has been found that the dust method is unreliable; too much of the chemical is lost on windy days; the small amounts needed for turf make it difficult to apply evenly without diluting it with some inert material. The poisonous character of the mercury fungicides makes it unsafe to breathe any of the chemical, which can scarcely be avoided if the material is distributed as a dust.

When chemicals are applied in the dry state they should, to obtain best results, be mixed with comparatively-dry, finely-screened topsoil, compost, sand or other material that will increase their bulk and render even distribution more likely. In mixing the chemical with dry materials it is necessary to obtain a uniform mixture and to pulverize all the lumps of the chemical, for if lumps of a concentrated chemical are permitted to lie on turf they are likely to cause severe local burns. An excellent method of mixing a chemical with soil is to first mix it with a small quantity of dry, sharp sand; preferably about twice as much sand as chemical should be used. These are then rolled together with a rolling pin, a piece of pipe, or a bottle. In rolling them together the lumps are broken by the grinding action of the sand. The rolling and mixing should be continued until a uniform mixture is obtained as indicated by the absence of streaks. The chemical and sand can also be forced through a very fine screen, but this will not result in as fine a mixture as rolling. The material to be applied to the turf is spread out on a tight floor or smooth concrete so that it is in a layer not more than 2 or 3 inches deep. The chemical and sand mixture is then scattered over it, raked in thoroughly, and shoveled over several times so that it is uniformly mixed. A revolving barrel churn, a small revolving concrete mixer, or even a homemade mixer, may also be used for mixing the chemical and sand with the bulky material.

Storage of mixtures of mercury fungicides and soil, compost, or fertilizers for short periods does not destroy the effectiveness of the fungicides. It does, however, lessen the danger from burning, even when allowed to stand overnight after mixing. If such a mixture is allowed to stand from one season to the next it loses some of its effectiveness. Some, however, is retained so that when one has a

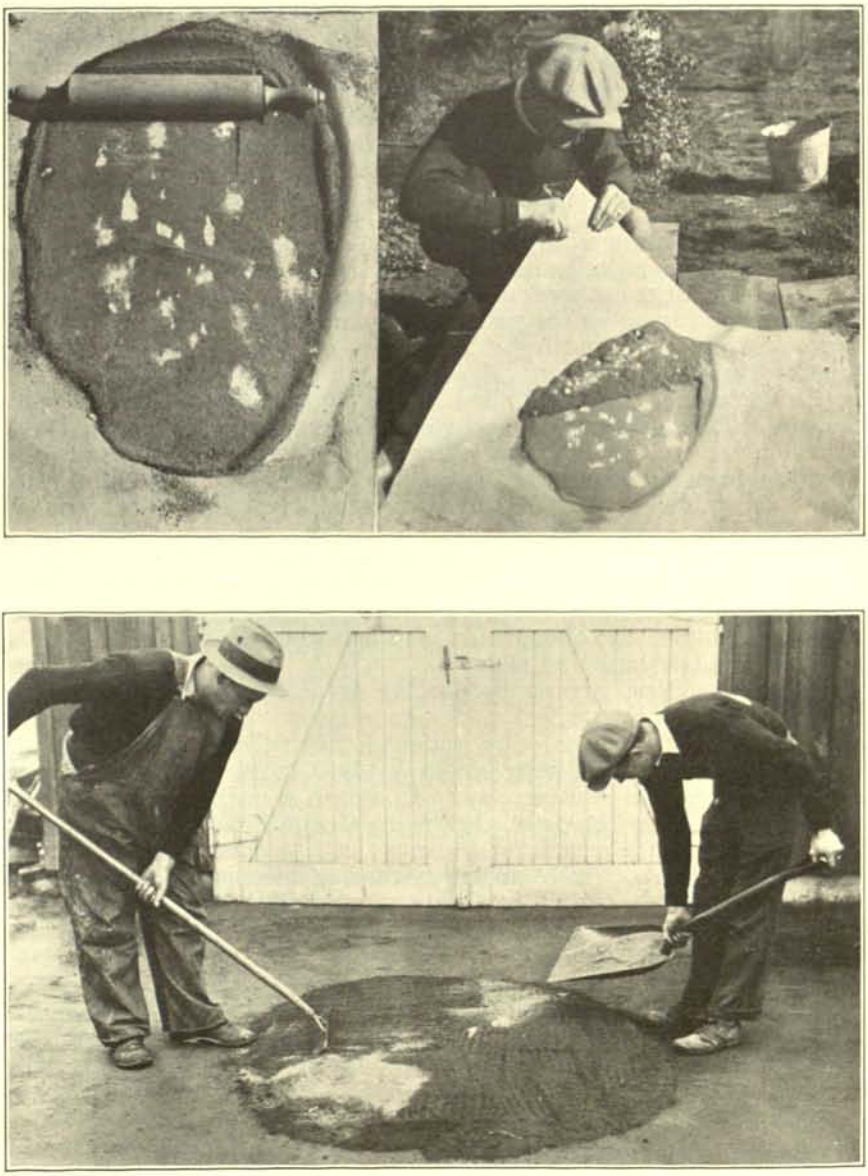

Figure 21.—On many golf courses fungicides are distributed dry, mixed with sand, compost, or similar material. To insure even distribution with this method all lumps of chemicals should first be broken. An effective method for accomplishing this is by rolling and mixing them in fine sand (above). This is best done on a piece of heavy paper or canvas, which can be lifted at the corners to throw the rolled material back into a pile and expose new lumps to the rolling operation. The rolling and piling are repeated until no lumps remain in the mixture. A pile of screened soil is then spread out and the mixture of sand and fungicide is spread evenly over the pile and worked in with a rake (below). The pile is then turned over several times to make a thorough mixture.

supply already mixed it may be used, but to be effective it must be used at higher rates. It is advantageous to mix enough material to meet the demands for treatments for about a month in advance so that when disease occurs it can be promptly treated.

When the dry materials are to be broadcast over the turf, an 8-quart bucketful applied to 1,000 square feet is a fair amount to use, but the quantity depends on the preference and skill of the man who applies it. Some men can broadcast a small amount uniformly; others prefer a larger amount. The amount of fungicide should be weighed and mixed with a definite quantity of material so that each bucketful contains the amount of chemical that is to be applied to a definite area. A large amount of material can be mixed at one time so that applications can be made whenever they are needed and the mixture can be broadcast over a green at the rate of a bucketful to 1,000 square feet, or at any other rate that is preferred to obtain even distribution.

Fungicides are often mixed with fertilizers to give them greater bulk. Such fertilizers as cottonseed meal, activated sludge, poultry manure, and other organic or dry fertilizers are suitable for such use. The fertilizer does not reduce the effectiveness of the fungicide nor does the fungicide affect the fertilizer. The fertilizer and fungicide can be given additional bulk by mixing with sand, topsoil, or compost so that a bucketful contains the amount of fungicide and fertilizer that is to be applied to 1,000 square feet. In some cases the fertilizer is bulky enough so that addition of other material is unnecessary. The amount of chemical then added to the fertilizer should be such that the amount of fertilizer it is desired to apply to a green contains the quantity of fungicide required for that area.

Dry materials are usually broadcast from buckets by hand. It is customary to apply two thin applications in opposite directions, as in seeding. This helps to prevent uneven distribution, which might cause injury by concentration, or continuance of disease in small areas which have been missed. Sometimes the application is made with a topdressing machine or a fertilizer distributor. When the dry method is used masses of the material on the turf give evidence of any careless or uneven distribution. The turf may be dragged with a steel mat or some similar equipment, or poled with bamboo poles in order to increase the evenness of distribution. However, the drag used should be light-weight since any bruising of the grass may result in burning.

Mercury fungicides may also be applied when mixed with topdressing materials. By this method the fungicide is applied at the time of topdressing the putting green. However, the labor involved in mixing the fungicide with the topdressing material is usually more than is saved by the necessity of making only one application. It is also very difficult to mix the small amount of chemical directly with the large amount of compost that is needed to topdress a green. It is best to first mix it with a small amount of sand as has been suggested above and then mix it thoroughly through the topdressing material. Uneven distribution often results from the application of fungicides in topdressing because of the difficulty of obtaining a uniform mixture. It is not recommended in most cases. In many instances fungicides must be applied more often than the turf needs topdressing and other methods must then be used.

Liquid Methods of Application

The mercury fungicides are of two types; those which are soluble at rates used on golf courses, and those which are insoluble. Soluble chemicals are those that disappear after being placed in water for a time. Examples of soluble chemicals are corrosive sublimate, sulphate of ammonia, and common table salt. When these chemicals go into solution they diffuse to every part of the liquid so that each unit volume of the liquid contains an equal amount of the chemical. To evenly distribute such chemicals to turf it is only necessary to make a uniform application of the liquid on all parts of the turf.

Although corrosive sublimate is soluble in amounts used on golf courses, the process of dissolving it in cold water is often slow. Some chemicals dissolve much more rapidly in water in the presence of another salt in solution. Corrosive sublimate dissolves rapidly in water if there is added with it ¼ its weight of common salt or ammonium chloride. Four pounds of corrosive sublimate quickly dissolves in a gallon of water to which 1 pound of salt has been added, but without the salt it will not dissolve in that quantity of water. This amount will treat approximately 22,000 square feet of turf, or four moderately-sized greens. During the hot summer weather this amount used at reduced rates will treat eight putting greens. The solution may be prepared in glass jugs, earthenware jars, or wooden kegs. Corrosive sublimate solutions should never be placed in metal containers because of their corrosive action on metals. Not only is the container corroded but the solution is weakened and it is impossible to determine the quantity of such a weakened solution that is needed to get the desired control of disease. As corrosive sublimate damages metal parts, the equipment should be washed thoroughly after being used.

Insoluble chemicals are those which do not disappear when placed in water. Examples of these are calomel, arsenate of lead, and lime. When these chemicals are placed in water they settle to the bottom of the container so that the liquid above contains practically none of the chemical. In order to make uniform applications, these chemicals must be finely ground and must be kept constantly stirred so that the chemical will be suspended in the liquid in much the same way that fine clay particles are suspended in muddy water. Some chemicals remain suspended in the liquid for longer periods than other chemicals. The insoluble mercury compounds, such as calomel, are very heavy and settle quickly unless vigorously agitated. When calomel is to be applied to turf, therefore, it is not only necessary to apply the suspension evenly but constant agitation must be provided so that each unit volume of the suspension contains an equal amount of the chemical. Neither salt nor ammonium chloride will aid in dissolving calomel.

It is often easy to become careless with the liquid treatments and to slop or spill quantities of the material on turf. Such carelessness is not immediately detected when the material is in solution for there is no excess apparent on the surface as is the case when dry materials are spilled. Carelessness of this kind, however, in a few days often results in areas of dead turf that take a long time to heal.

Many golf clubs have power sprayers which they use for applying fungicides and fertilizers to turf and for spraying trees and

shrubbery on the course. The cost of such equipment is considered prohibitive on some courses. Some greenkeepers feel that they can treat their putting greens in less time with spraying equipment than with other methods and reduce the cost of treatments. When applications of fungicides or insecticides are made to coat the leaves with poison as is the case with many plant insect pests and diseases, spraying equipment is most effective. This is also true when small amounts of corrosive sublimate are applied at frequent intervals to check disease.

Figure 22.—Fungicides when thoroughly mixed in water can be readily distributed over a putting green in the form of a fine mist by means of a power sprayer and suitable nozzles. Success with this method depends chiefly upon the method of using the equipment.

With the power sprayers in use today it is not necessary to resort to the high dilution generally employed with sprinkling devices. A solution of from 5 to 10 gallons for 1,000 square feet is adequate to distribute chemicals evenly on putting greens, and some careful greenkeepers can use even less. The advantage of high-powered spray equipment becomes evident only when the spraying operation is conducted in a systematic way. For example, concentrated solutions or suspensions of the fungicide to be applied should be taken out on the course with the spray wagon so that it is not necessary to wait for the chemical to dissolve in the tank. The quantity of chemical in the solution should be known so that a definite amount can be measured into each tankful of water. The area of each green should be determined and the quantity of the solution or suspension to be used should be calculated so that all guessing will be eliminated. Many spray wagons have two compartments, and it is usually possible to fill one tank from a water outlet near the putting green while the green is being sprayed from the other tank. Two hose lines and nozzles are generally used in spraying the green. In any case the operator or operators should be trained to walk back and forth over the putting

green at a uniform pace in order that each portion of the green may receive the same amount of spray. With two operators the custom usually is to start at opposite sides of the green, and walk over it, back and forth, each on parallel lines, getting closer on each trip across the green until they meet at the center. After some experience the operators learn how fast they must walk in order to cover the area of the green 2 or 3 times with the quantity of liquid in the tank. The more often the operators can go back and forth over the green the more likely it is that the solution will be uniformly applied. Since bad burns may result from leaks it is quite important to have all connections in the tank and hose absolutely tight.

On certain small courses, particularly in the Northern States, where the turf diseases do not occur frequently, it is possible to apply fungicides to the affected areas with a sprinkling can. The chemical first should be dissolved or mixed with water in a wooden barrel in such a quantity that 50 gallons of the mixture will treat 1,000 square feet. For instance, if a treatment of 3 ounces of calomel to 1,000 square feet is desired, that amount of the chemical should be placed in 50 gallons of water. In that case, 1 gallon of the mixture will treat 20 square feet, which is an area 4 feet wide and 5 feet long. The tendency is to apply too large amounts of chemicals by this method and thus cause burns. It is well to treat an area of 20 square feet with a gallon of the liquid wherever the disease is present. It is important that the gallon in the sprinkling can be distributed uniformly over the area. Each time before a canful is removed from the barrel the mixture should be vigorously agitated so that the chemical will be in suspension. When applying the fungicide with a sprinkling can great care should be taken not to spill the liquid on the green as serious burns may result. The amount to be applied should be sprinkled on the turf in two applications which are sprinkled in two directions. However, applying fungicides by the sprinkling-can method is slow and where any large areas of turf must be treated this method is too expensive, and other methods should be used.

Barrel-sprinklers are often used on golf courses to apply fungicides. These use a dilution of 50 or 100 gallons of water to 1,000 square feet. It is necessary to stir constantly to keep insoluble materials in suspension, and it is also necessary to keep the distributing bar horizontal when moving over slopes to prevent one side from getting all of the treatment while the other side gets none. The operator should move quickly over the green so that he can cover it twice in two directions with the allotted amount of liquid for the area. Care must also be taken that he does not overlap the treatments since that would result in burns due to doubling the rate of application.

Proportioning machines of various types have been used for applying fungicides on golf courses. These can only be used with the soluble fungicides. The principle involved in proportioning machines is that a concentrated solution is drawn out of a container through a siphoning arrangement by the water from an ordinary watering outlet. Mechanical imperfections and varying water pressures at the outlet make it impractical to make uniform application with such apparatus and they are not widely used on golf courses.