

Use of Peat and Other Organic Materials on Golf Courses

By John Monteith, Jr. and Kenneth Welton

The value of peat and muck for soil improvement has been a subject of much interest and discussion for many years. These materials have been extensively used on golf courses for a long period. In many cases the results obtained have been favorable but in all too many instances damage to turf has resulted from their use. The contradictory reports of results have clearly indicated that further information is needed on this subject before uniform benefits can be expected from these materials. There has been ample evidence that the contradictions have been largely due to some improper use of the material, or the selection of the wrong type of material. American golf clubs have no doubt wasted many thousands of dollars during the past two decades in the application of peats and mucks, or their supposed equivalents, to courses. On the other hand, during this same period huge quantities of these materials have been profitably used on golf courses. It is the purpose of this article to briefly summarize available information on this subject in order that some of the large waste of the past years may be avoided and that the materials may be used to better advantage and with more uniform satisfaction.

A number of years ago an entirely wrong impression of peat generally existed among golf clubs. Clubs purchased large quantities of this material at fancy prices and used it for some purposes for which peat was unsuited and in a manner which caused harmful results. With the widespread disappointment following its use it fell into general disrepute and it has only been in recent years that its proper use has been generally realized.

In past years a great deal of peat was sold to golf clubs for the purpose of providing a moisture-retaining layer in putting greens. Clubs were induced to put layers of peat several inches thick in the greens. These layers, laid from 6 inches to over a foot below the surface, were supposed to be for the purpose of conserving moisture. This practice for various reasons produced bad results and greens thus constructed had to be rebuilt at considerable expense. Peat was also used in pure form as topdressing sometimes because it was considered to be rich in plant foods and sometimes in an attempt to soften the surface of hard packed greens. These layers of peat became buried under subsequent topdressings of soil and, even though the layers were thin, caused trouble, especially at certain seasons. The troubles arising from these methods of using peat were due to the manner of using the material, and they largely could have been avoided by using peats in soil mixtures as clubs are learning to do today.

Peat was also sold to golf clubs as a valuable fertilizer material. As a fertilizer, peat has never been able to produce results on turf that would justify its purchase, even at prices much lower than those usually demanded. Therefore when it was sold on the basis of its fertilizer value it could not long continue to compete successfully with the many commercial fertilizers on the market.

The widespread interest in peat and the rather general impression that it has unusual plant food value are not based on the performance of peat itself but upon the productivity of certain rich soils that are confused with peat. River bottom land is usually the richest in any

district. Likewise reclaimed land resulting from drainage of ponds or lakes is usually found to be highly productive. Such soils are usually dark in color and contain an abundance of organic material, so it seems only natural to assume that all soil materials that are water-borne or are deposited under water will be extremely productive when made available to growing plants. This assumption is not justified, however, because there is an important difference between water-borne silt or mucks and peat. The rich black soils that are so commonly referred to as peat are in reality classed as silty peats. These soils have been made by clay or silt being deposited in peat beds. The mixtures of mineral soil and peat, upon cultivation, are capable of producing extremely heavy crops. Some golf courses have been built on this type of soil and invariably when properly fertilized have soon been covered with a heavy growth of turf which has been easily maintained. In some instances soil of this type has been used for topdressing putting greens for a number of years with entirely satisfactory results. Such experiences have led to the belief that all dark colored soils or peats are desirable for golf course turf in their natural condition.

Peat, Muck, and Humus Defined

To the layman the terms peat, muck, and humus are usually regarded as synonymous. To one acquainted with these materials the terms are by no means interchangeable. There is, however, a close relationship between them, for the origin of all three is the same, namely dead organic material. Peat is past centuries' accumulations of wood, sedges, mosses, and similar material which are packed together and preserved, under water or near the water level, through the ages in a partially decomposed condition. When peat is further decayed it breaks down into a finer form called muck, in which form it is usually found mixed with clay or silt. Still further decomposition changes the material into what is commonly referred to as humus. It has been estimated that 2 to 6 parts of organic material may break down in soil to form 1 part of the residue commonly referred to as humus. Since peat, muck, and humus represent various stages of decay there are no sharp dividing lines between them, and since they originated from many different types of vegetation, it can be readily understood why there should be such striking variations in the material classed under these names.

Peat and muck may be derived from any vegetation, including large trees or delicate mosses, which means that the texture varies according to the relative proportions of the coarser or finer constituents. Also the texture varies with the stage of decomposition. The color, mineral content, and other characteristics vary in different peat and muck deposits. All these variations make it impossible to predict with any degree of certainty just what results can be expected from the use of peat or muck on a golf course.

Peat and muck may be black and in general appearance resemble well-rotted manure. Rotted manure is full of organisms, including bacteria and molds, which are helping the decay of the manure, and changing the plant foods contained in the manure so that they will be readily available to roots of plants when applied to the soil. In the case of peats there are relatively few organisms present and no decomposition of the material in the natural state. They contain some plant food but it is chiefly in a form that is not available to plants

for many months, or even years, after it is applied to soil. Therefore in spite of the general similarity in appearance and in some chemical characteristics of peat and humus to well-rotted manure, it should be recognized that they behave differently. Since the final stage in the decomposition of peat or muck is humus, just as in the case of animal manures, it follows that ultimately they will all have some similar effects on soils. Most soils to encourage best plant growth require an ample supply of humus, and any material that will supply this humus to golf course soil is desirable provided it does not at the same time introduce harmful factors.

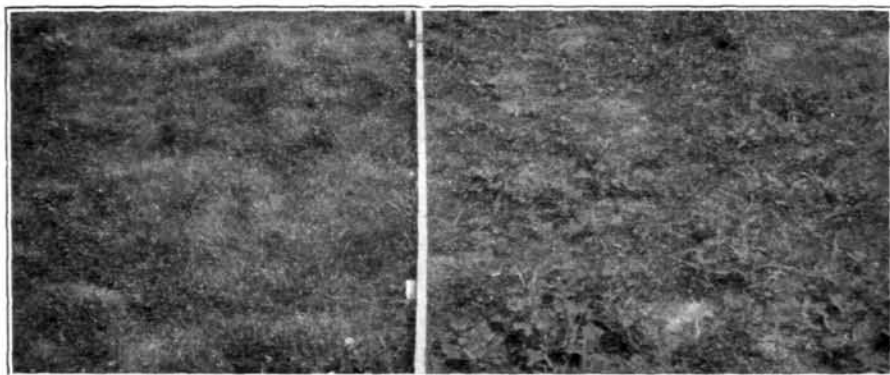
Organic Material Required in Soils

When most of our agricultural land was first put into cultivation it contained ample supplies of organic material. Organic matter is necessary for the activity of the microorganisms in the soil which are responsible for maintaining the supply of nitrogen. Hence soil fertility is nearly always associated with organic matter and under suitable conditions, and up to a certain extent, the higher the organic content the higher the nitrogen supply. The constant cropping of much of this land with faulty agricultural methods has gradually reduced the organic content of many of our soils. The gradual loss of organic material combined with the losses of mineral plant foods through cropping and leaching have resulted in the impoverishment of many soils that were once highly productive. In recent years the need for the replacement of organic material and mineral elements to soils has been generally realized. Golf courses because of certain topographical advantages or monetary considerations frequently have been built on properties where the soil has long been exhausted, and therefore the problem of restoring the organic material and fertility of soils is one that is presented to a large number of golf clubs throughout the country. Organic material decomposes and is lost more rapidly in sandy soils than in clay soils. It also is lost from soils in the South more rapidly than from similar soils farther north. Therefore on some courses organic material must be constantly replaced even though there may have been no great deficiency at the time of construction.

Many golf courses are built on land which had been exhausted by years of faulty farming methods, and many other courses are built on land so poor that it was never worth farming. The fertility and organic content of such soils are woefully deficient. On many other golf courses faulty methods of construction resulted in the burial of good topsoil in making fills and the covering of large areas with subsoil or extremely poor grades of topsoil. Some of this poor soil has even been used for the surfacing of putting greens. Since organic material is an essential ingredient of a productive soil, it naturally follows that the problem of supplying even a minimum of organic matter to the soil is an important problem on the large number of courses where the surface soil is insufficiently supplied to provide for even the normal requirements of turf. Many desperate and costly attempts have been made to provide the essentials of plant growth on golf courses handicapped by poor soil.

In the early days of golf courses in this country the usual method of restoring both fertility and organic matter was by the use of animal manures. In more recent years, however, the animal manures have been more difficult to obtain and more expensive than in years

gone by. It also has been recognized that animal manures are badly contaminated with the seeds of weeds that are troublesome in golf course turf. The objection of weed seeds can be overcome by proper composting, by sterilization, or other methods to destroy the weed seeds, but all these methods add to the cost of using manures.



Manure is usually badly contaminated with weed seeds whereas peat is practically free from them. The plot at the left contained peat and soil; the plot at the right contained manure and soil. Since the source of that soil was the same in both cases it is evident that the large number of weeds in the plot on the right was due to the manure.

Commercial fertilizers have been extensively developed in recent years and have been rapidly gaining in favor among both farmers and greenkeepers. More efficient production methods have resulted in a gradual reduction of the cost of commercial fertilizers, so that now fertilizer elements can be applied on most golf courses more economically in the form of commercial fertilizers than in the form of animal manures, especially the bulky types. It has been found that in many soils manures rapidly disintegrate. Even where an abundant supply may have been worked into the soil before the turf was planted there may be little of its organic matter left in the soil in the course of relatively few years. Tests with manure applied to the surface of established turf have left serious doubts as to its greater effectiveness in raising the organic content of the soil as compared with corresponding quantities of fertilizers applied in commercial form. Consequently there has been a constant increase in the interest in replacing the organic matter of manure for golf course use with some other form of material that is weed-free, more economical, and most lasting. All sorts of organic materials have been used in an attempt to restore the organic material to golf course soils, and peats and mucks have been in common use for this purpose. Efforts to build up relatively high organic contents of soil have been especially concentrated on the putting greens, where the best turf on the course is demanded.

Peat and other forms of organic material have been used on golf courses for many years for mixing in the soil during the construction period, and for topdressing established turf. Many of the results obtained have been entirely satisfactory, but there are many instances where these materials have not only failed to give the desired results but where their use actually has proved to be harmful. Such

contradictory results clearly indicate that something is wrong in the use of these materials. In some instances it has been apparent that the wrong materials have been used, in other cases the methods of using them have been at fault, while in other cases the cause of the disappointing results have not been apparent. In spite of the extensive use of materials of this kind and the obviously great wastage of club funds due to their haphazard use there has been little experimental work done with them to help furnish the information needed to determine the proper kinds of material to use under different soil conditions and the best method for using them. These attempts have too often given little or no benefit or at least only a temporary benefit. One of the outstanding needs of modern turf culture is more information as to methods for permanent improvement of these extremely poor soils.

Experiments With Peat and Other Organic Materials

In order to obtain more information on the subject of improvement of the soil for golf courses with the aid of organic materials, especially peat, some experiments were undertaken at the Arlington turf garden and the Mid-West turf garden by the Green Section in cooperation with the Bureau of Chemistry and Soils, United States Department of Agriculture. The results of these tests to date will be referred to briefly throughout this discussion. These tests were designed primarily with the purpose in mind of permanent soil improvement, and therefore the observations that shall be made several years hence should be of much more interest and practical value than these preliminary observations. There are many methods known to give rapid and economical stimulation to turf. In the case of peat and some other forms of organic matter, however, the Green Section feels that the added cost involved can be justified only by greater permanence of benefits than can be obtained by the well-known cheaper treatments that are now available.

Peat, muck, charcoal, and certain waste products have offered possibilities for the replacement of exhausted organic matter in soil. Some of these materials are distinctly more economical to use than manure, are free from weeds, and have indications of great permanence. Unfortunately some of them have possibilities of causing harm to turf; others, although not actually harmful, may be of little value, either temporary or permanent. It was the purpose of the tests to determine some of these advantages or disadvantages.

Series of plots were prepared at the Arlington turf garden and at the Mid-West turf garden to test the value of sand and various kinds of peat and other forms of organic matter when mixed in the top few inches of soil used for putting green turf. Some plots were included also to test the use of peat in the pure form as a surface mulch. The mixtures were used in surface layers of different depths. To accomplish this the soil was removed to the desired depth and the subsoil graded at the same slope as the surface of the finished plots. The required amount of soil for each plot as well as the peat or other materials were screened, with a suitable sized mesh to break down aggregates and to put the material into its typical finely divided condition. The soil and other materials were put in a large mixing box and turned over several times as in mixing concrete. Boards were placed around each plot to keep the mixtures separate and each mix-

ture was then put in the plot and leveled, rolled and prepared for planting in the usual manner of planting putting green grass.

The materials tested at the Arlington turf garden included two samples of sedge peat from different sources, two samples of reed peat from different sources, a sample of reed muck, imported moss peat, leaf mold, cottonseed hulls, buckwheat hulls, manure, and charcoal. The materials tested at the Mid-West turf garden included two samples of sedge peat from different sources, a sample of raw reed peat, two samples of cultivated reed peat from different sources, a sample of kiln-dried reed peat, one sample of imported moss peat, one sample of domestic moss peat, manure, and charcoal.

It is recognized that peat and other organic materials may be of much value in improving fairway and tee turf. The greater interest in their use for putting greens and the decided limitation of facilities for the tests, made it seem desirable to restrict the tests chiefly to putting green conditions. The general application, however, of some of the observations obviously can not be limited to putting green turf.

How Organic Matter Helps Soils

Organic matter performs several important functions in the improvement of mineral soils. One of the most important of these functions is to improve the structure of the soil by making the soil more granular and preventing its tendency to become hard and baked. Sticky clay soils are particularly benefited in this manner. The surface of putting greens having a plastic clay soil is especially undesirable, since such a soil gives a soggy surface when wet and unusually hard surface when dry. This condition is decidedly undesirable from the standpoint of play, and it is also likely to be troublesome from the standpoint of grass growth. Some form of organic material in conjunction with sand is generally used in changing the structure of clay or fine silt for golf course purposes. Various methods have been devised for measuring the plasticity or cohesion of soils. Some of these methods, together with suggestions for the use of different materials for changing an undesirable soil structure, are discussed in the Bulletin for February, 1932.

On fine textured soils peats exert a most striking effect by improving the structure of the soil. In this respect they are much more effective than sand. In fact on certain soils the addition of even as much as one-third sand has been observed to make the soil harder when dry. Peats improve the granular structure of fine soils and seem to lessen their plasticity. Fine soils to which sufficient peat has been added offer better growing conditions for the plants and improve playing conditions by giving the soil a certain resiliency even when dry. Tests conducted by the Green Section showed that a clay loam soil became puddled under fine turf conditions and became very firm and hard when dry. The same soil treated with peat two years previously was twice as easy to penetrate with an implement for testing the firmness or tenacity of the soil.

Peats also may be used to good advantage on sandy soils although for a different purpose than on finer soils. The comparatively coarse sand particles form a soil that is too loose and porous. The peat has a binding effect and retards percolation, and increases the water retention.

Another important function of organic material in soil is to increase the water-holding capacity. The water-holding capacity of a

soil is a measure of its ability to retain water against the pull of gravity. Since water drains away from sandy soils rapidly they have a low water-holding capacity. Clay soils, on the other hand, are able to retain much larger quantities of water than the sandy soils. Many forms of organic material are able to retain huge quantities of water, and when mixed with soil these materials generally increase the water-holding capacity of the soil. It has long been known that the water-holding capacity of a soil is not an accurate measure of its ability to supply moisture to plants, for the reason that much of the water so retained is held in such a condition that it is not available for use by plants. The amount of this water that is available to plants varies decidedly with the different types of soil and especially with the different types of organic material contained in the soil.

For many years much importance has been attached to the large water-holding capacity of peat. It has been pointed out that some peats will hold as much as 30 times their own weight of water. Large figures representing the water-holding capacity of some peats have been frequently misinterpreted to indicate that such materials will provide ample reservoirs of water in the soil which will provide plants with moisture during dry periods.

TABLE 1.—EFFECTS OF DIFFERENT KINDS OF PEAT ON THE PHYSICAL PROPERTIES OF A CLAY SOIL.*

Type of peat added to clay soil in equal proportions by volume	Weight per cubic foot	Loss on ignition	Moisture content air-dry	Maximum water-holding capacity	Moisture retained per cubic foot air-dry soil	Maximum water per cubic foot
	Pounds	Per-centage	Per-centage	Per-centage	Pounds	Pounds
Moss peat, poorly decomposed	38.63	14.1	2.22	104.6	.86	40
Sedge peat:						
Poorly decomposed	48.75	16.1	2.09	76.0	1.02	36
Partly decomposed	45.62	24.4	2.81	88.1	1.28	39
Reed peat, partly decomposed	55.74	17.2	2.52	72.4	1.40	39
Reed muck:						
Largely decomposed	58.54	20.4	3.38	67.9	1.98	38
Well decomposed	60.92	24.1	4.07	76.0	2.48	44
Untreated clay soil	79.26	3.7	.76	42.1	.60	33

* Analytical data by I. C. Feustel.

The relative importance of the water-holding capacity of peats in connection with improvement of soils for putting green purposes has undoubtedly been much overrated in the past few years. There have been many tests made under control conditions which indicated some decided benefits from peat in the growth of grass primarily from the standpoint of the increased water-holding capacity of soils containing peat. Some of the experimental work conducted by the Green Section, together with observations on golf courses, has indicated that in a practical way a large increase in the water-holding capacity of soils by the addition of extremely large quantities of peat may not be as great an advantage on putting greens as has been claimed. An excessive retention of water in the surface layer of putting greens may be decidedly detrimental, for it keeps the surface soggy and in a condition that can be easily marred by footprints,

which result in unsatisfactory putting surfaces. It has often been observed that, in some cases where the water-holding capacity of the soil has been increased by the addition of excessive quantities of certain peats, some other factor is involved, which leads to a rapid escape of the water from the surface layers during dry weather. Undoubtedly there are many instances where the additional water-holding capacity of peat is an advantage on putting greens even though many of the present opinions as to the value of this particular characteristic of peat are greatly exaggerated.

Table 1 shows the effect of some of the peat materials, used in the tests at the Arlington turf garden, on certain physical properties of the natural clay soil. Samples were taken a year after the plots were planted. It shows the effect of peat and muck in reducing the weight of the soil samples. This is partly due to increasing the pore space of the soil and partly due to replacement of soil with an equal volume of a lighter material. "Loss on ignition" indicates the amount of organic matter contained in the mixture and shows that the poorly decomposed materials add less organic material to the soil than do equal volumes of materials that are decomposed.

The moisture content of the air-dry samples represents a measure of the amount of water that would be maintained in the soil mixtures if the plots were allowed to thoroughly dry out in a natural manner at average summer temperatures. These figures show the relative amounts of moisture retained by the different samples. When the weight of a cubic foot of the soil or the mixture, shown in the first column, is multiplied by the moisture content, shown in the third column, the result represents the total amount of water retained in a cubic foot of the soil or mixture when exposed to the air for natural drying. These results are shown in the fifth column. It will be noted that the moss peat mixture when air-dry retained little more water than did the clay soil of the check plot. The more thoroughly decomposed peats retained more moisture than did the others. The small amount of water retained in the peat and poorly decomposed sedge peat mixtures, in spite of the large water absorbing capacities of these peats, may help to explain the tendency of these plots to dry out to such an extent that they fail to take water as readily as the other plots.

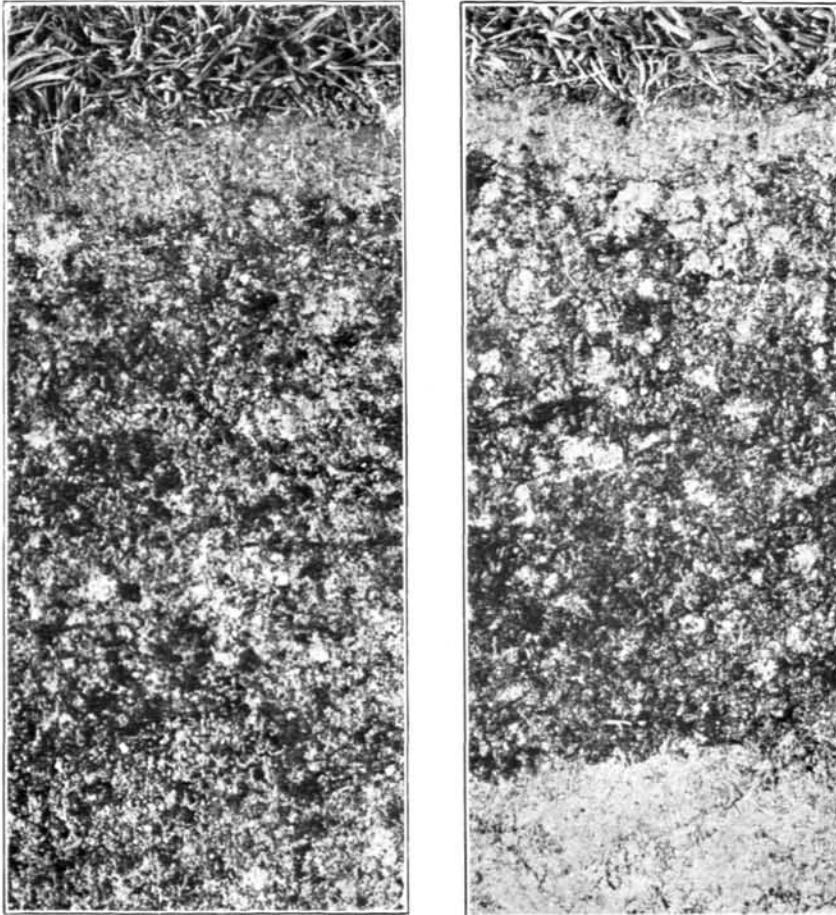
It will be noted that the water-holding capacity of the moss peat mixture was much greater than the reed or sedge mixtures and that these latter were much greater than the check plot. However, since the water-holding capacity is based on the weight of the mixture, it is apparent that the figures do not represent the actual difference in amount of water. In order to show the approximate amount of water contained in each cubic foot sample the oven-dried weight was calculated from the data in the table and multiplied by the figures in the fourth column. The sixth column contains the figures so calculated. They represent roughly the total amount of water contained in a cubic foot of the material when it contains all the water it will hold against the pull of gravity. This means the amount that is contained in soil when it is thoroughly wet but when all excess moisture has drained away. It therefore represents the maximum amount of water held in these soils, but plants can not use all of this water. It will be noted that in spite of the great variation in the water-holding capacity figures for these different materials, the actual amount of water they hold in soil does not vary

as much as is ordinarily supposed. Thus in the case of the reed peat the water-holding capacity is 72.4 compared with 104.6 for moss peat. The actual difference in the amount of water held in a cubic foot is only one pound. A comparison of the well-decomposed reed muck with moss peat shows a water-holding capacity of 76 as compared with 104.6. The mixture with the lower water-holding capacity, however, holds four pounds more water in a cubic foot than does the moss peat mixture. It is recognized that there are other factors that should be considered to give accurate data for such comparisons. Nevertheless, the above calculations are sufficiently accurate to justify serious questioning of some of the claims as to superior qualities of certain peats for golf course use primarily because of high water-holding capacity of the materials.

Organic material in the soil has an important influence on the activities of microorganisms that inhabit the soil. Many of these microorganisms have an important influence on the growth of plants. They play an important part in the breaking down of plant and animal refuse in the soil, including the dead roots and leaves of the plants that are living on the soil. Directly or indirectly they are responsible for many of the chemical changes that take place in the soil, and are constantly changing some unavailable plant foods into forms that are available for use by the higher plants, such as those that form turf. Some of the microorganisms in the soil cause diseases in plants and therefore are undesirable. The big majority of them that occur in soils are organisms that are beneficial. Rotting manure is full of organisms that cause decay, and when such manure is added to soil it stimulates the activities of soil bacteria and other soil organisms. Peat, on the other hand, is usually not a favorable medium for the growth of microorganisms, and when it is applied to soil without fertilizers, especially those containing ample nitrogen, it usually does not result in the decided stimulation of microorganisms, as in the case with manure. When a sufficient supply of fertilizer or lime is added with the peat to soil there may be a decided increase in microorganisms. This activity may result in a complete utilization of available plant foods by these microorganisms and a resulting apparent starvation of higher plants such as grass.

Certain forms of organic material when added to soil greatly increase the pore spaces and result in better aeration and facilitate the movement of air and other gases through the soil. Adequate aeration of soil is considered essential for proper plant growth. It is necessary for free circulation of air in the soil to provide the plant roots with oxygen. It is necessary for the work of the many microorganisms in the soil which produce decay of organic matter and supply the nitrogen and carbon dioxide which is necessary for plant growth. Oxygen in the air also effects chemical changes which produce soluble mineral nutrients in the soil. Peat is most beneficial in fine soils by increasing the porosity of the soil and thus allowing the plant roots to easily penetrate the soil and grow to greater depths in their search for moisture and plant foods. Constant trampling of soil, such as occurs on putting greens, tends to reduce the pore space and seriously affects the aeration of the soil. In some cases it may be possible to increase the pore space too much for the welfare of the plants. In some of the plots at Arlington, particularly those where peat moss was used in excess

or where buckwheat hulls and cottonseed hulls were used, the moisture seemed to escape too rapidly. This may have been due in part to excessive pore space. The effect of peat in increasing the pore space may be seen in the illustration of sections of soil and a soil-peat mixture taken from plots on the Arlington turf garden.



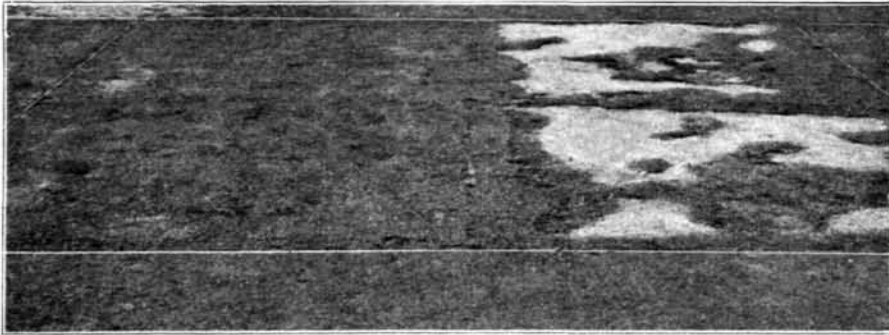
Effect of peat and sand in improving the soil structure. At the left is a cross section of turf growing on a mixture of $\frac{1}{3}$ clay, $\frac{1}{3}$ moss peat, $\frac{1}{3}$ sand. At the right is a section of turf on a 4-inch layer of $\frac{1}{2}$ clay, $\frac{1}{2}$ moss peat. Beneath this layer is the natural clay soil used in these mixtures.

Organic material in soils generally is an aid to root penetration. This may be a mechanical aid due to improved soil structure, or the indirect aid of better aeration, drainage, or other factors. Whatever may be the cause, it is generally found that better root development occurs where the soils are well supplied with humus, provided there is no toxic material present to inhibit root penetration.

Organic material in the soil also has the capacity to absorb certain chemicals in solution and may at times prevent some chemical

injuries. In some instances this may be due to a chemical change; in other instances it may be due to the movement of water through the soil. It has been observed at the Arlington turf garden that peat in surface soils checks the harmful concentration of salts at the surface.

Soon after the seedlings were well established on the series of peat tests at Arlington, an attack of brownpatch occurred and injured much of the turf in all of the plots. Dry weather followed and it was observed that the grass recovered from the brownpatch in the plots containing peat but that in the check plots the grass failed to recover. These dead areas were raked lightly and reseeded. Some



Effect of peat in preventing concentration of salt at surface. The turf in the damaged plots on the right is growing on bare clay and the healthy turf on the left is growing on similar clay to which peat has been added; moss peat in the front plot and sedge peat in the rear plot. All the plots were given similar heavy rates of fertilizers before planting and all had received similar cultural treatment. The soil in the dark patches is frequently covered with a thin incrustation of salts.

seed germinated but was soon killed. This reseeded process was repeated several times with equally poor results, even in the fall when conditions were decidedly favorable for seeding. It was noted that during the dry summer months the dead areas gradually enlarged. The soil in the dead areas was examined and it was found that there was an excessive concentration of salts in the surface layer of soil. The highest concentration was in the center of each dead patch. At times salts were deposited in a thin crust over the surface of the soil. In all of these plots an excessive amount of fertilizer was added at the time of mixing the soil in order to make sure there would be no deficiency of plant foods. All the plots, however, received the same amount of fertilizer, and it was all thoroughly mixed in the soil, just as it was in the soil-peat mixtures. Therefore the concentration of salts in the check plots represented a movement of the salts to the surface rather than any concentration due to careless mixing. Where the concentration of salt in these injured areas was sufficient to check grass growth it probably increased rapidly, due to excessive evaporation from the bare soil. The nature of the injury is shown in the illustration.

Certain forms of organic material have been used as a mulch to prevent the excessive evaporation of moisture from the soil. Different types of peat have been used for this purpose. They have been used in a general way for many years as a mulch on flower beds

and are used in this manner on many golf courses. They have also been used as a mulch on turf immediately after seeding, and even on established turf. The chief objection to the use of peat as a mulch on golf course turf lies in the fact that it is likely to be blown off the bare areas, where it is most needed, in periods of drought, and at times of heavy rains it is washed from such areas and piles in ridges which may be a great inconvenience to play. In the experiments at the Arlington turf garden where peat was used as a mulch after seeding, there was evidence of a stimulation of growth, which appeared due to the effect of the peat layer in aiding the retention of moisture in the germinating layer of soil.

Peat Should Not Be Considered As a Fertilizer

As previously stated, peat at one time was used extensively on golf courses under the misapprehension that it was a good fertilizer. It is now realized that peat does not take the place of fertilizers. In fact, chemical analyses of peats show that most of them are decidedly deficient in fertilizing elements and certainly do not furnish these elements in sufficient quantity to justify their prices. At times when they are added to soils they not only fail to provide the stimulation expected of a fertilizer but they may actually serve to reduce the effectiveness of fertilizers for a time at least. When they are used on turf, therefore, peats should be supplemented with an adequate supply of fertilizer, especially one containing plenty of nitrogen. When so supplemented they can be expected to produce beneficial effects in soil improvement that may well justify their use independent of any fertilizer effects. Peat is sometimes used as a filler or a base for mixed fertilizers and as such is satisfactory for turf purposes.

In one test at the Arlington turf garden moss peat was mixed in the top four inches of soil just before planting in early September with Kentucky bluegrass and redtop. The plot received a complete inorganic fertilizer of the same kind and at the same rate as did the adjoining plot where no peat had been used. Germination in the two plots was about the same, but the young grass in the plot having no peat grew much more rapidly than in the plot containing peat. During the entire fall and until May of the next year, the grass in the plot containing peat appeared yellow and unthrifty, as if suffering from a fertilizer deficiency, especially nitrogen. In the adjoining plot of the same soil, receiving the same application of fertilizer as did the peat plot, the grass continued to grow vigorously and had all the appearance of a well-fertilized turf. In May the grass in the peat plot began to grow more vigorously and by midsummer the turf in this plot was entirely satisfactory. In later series at both the Arlington and Mid-West turf gardens the same retardation of growth was observed in many of the peat plots, especially in the period between late September and early May. Some of the plots where the grass appeared decidedly poorer than the check plots were divided and part of each plot received a heavy application of some form of quickly available nitrogen fertilizer. Wherever sufficient nitrogen was added there was soon a rapid growth of the grass.

The above observations throw some light on some of the contradictory results obtained with peat on golf courses. In many instances large quantities of peat have been used to improve soil for

golf courses without at the same time adding an ample supply of fertilizers. In some cases the peat has been used under the misapprehension that peat itself was a good turf fertilizer. In many such instances only detrimental responses were observed in the grass, and it has been often assumed that the harmful results were due to toxic substances in the peat. The above tests demonstrated that harmful results can come from using peat with insufficient fertilizer wholly independent of any toxic action. It is probable that the peat simply locks up much of the plant food in the soil by chemical, physical, or biological means. Regardless of the cause, however, it is evident that large quantities of peat can not be used without taking into account the fertilizer requirements of turf. This unfavorable response where insufficient fertilizer is available is especially important in regions where golf courses are used extensively during the cool seasons.

In the case of the plots in which as great a volume of organic matter in the form of manure was used, as was used in the peat plots, there was an excessive growth of grass which was too soft and succulent to withstand adverse conditions of summer. This rapid growth was probably due to the more immediate availability of the plant foods in manure than in the peat plots, even though they had been supplemented with commercial fertilizers to make them correspond to the manure plot. In the case of the cottonseed hulls the growth of grass was at first retarded but there was some stimulation the second year which apparently was due to the sudden release of its plant food when the lint and hulls were finally decayed. In the buckwheat-hulls plot there was a decided retardation in growth which was probably due to some other factor than its effect on fertility.

Different kinds of fertilizer were tested in two series of plots, one series containing European moss peat and the other series containing American sedge peat. These tests were to determine the effect of different types of nitrogenous fertilizers on soil and peat mixtures. Some types of peat are decidedly acid in reaction and have a tendency to increase soil acidity. It has been assumed that under acid conditions these peats are likely to be preserved longer than in neutral or alkaline conditions. For these tests three plots were used for each fertilizer. One plot contained the natural clay loam soil, the second plot contained a four-inch surface layer composed of 50 per cent of clay loam soil and 50 per cent of moss peat. The third plot contained a similar four-inch surface layer of clay loam but with 50 per cent of sedge peat instead of moss peat. All of these plots received equally heavy applications of superphosphate and muriate of potash thoroughly mixed through the top four inches. Into one of these sets of three plots there was well mixed a heavy application of sulphate of ammonia. Another set of three plots was similarly treated, but instead of the sulphate of ammonia these plots received an equal amount of nitrogen in the form of nitrate of soda. Three other plots were treated in the same way except that they received the same amount of nitrogen in the form of urea. The fourth set of plots was an exact duplicate of the third set, but it had added to it a heavy application of lime. All of the plots were planted in May, 1930. After the first year additional applications of nitrogenous fertilizers were added whenever the grass seemed to be in need of additional nitrogen. No further applications of superphos-

phate, muriate of potash, or lime were added. The effect of these fertilizers on the acidity of the soil is shown in table 2.

TABLE 2.—EFFECTS OF MOSS AND SEDGE PEAT AND CERTAIN FERTILIZERS ON THE PROPERTIES OF THE ARLINGTON CLAY SOIL*

Treatment of plot	Weight	Loss on ignition	Moisture content	Maximum water-holding capacity	Total nitrogen (N)	pH
	Lbs. per cu. ft	Per- centage	Per- centage	Per- centage	Per- centage	
Check-urea	74.27	3.8	.83	41.2	.06	4.6
Moss-urea	46.19	12.0	1.44	92.8	.12	4.4
Sedge-urea	56.17	15.7	1.78	72.6	.23	4.2
Check-lime-urea	76.77	3.3	.76	40.3	.04	6.4
Moss-lime-urea	51.18	10.7	1.45	84.6	.12	5.8
Sedge-lime-urea	59.29	14.4	1.72	72.2	.22	5.3
Check-sulphate of ammonia.....	76.15	3.4	.76	38.7	.04	4.1
Moss-sulphate of ammonia.....	44.31	12.1	1.55	93.0	.13	4.1
Sedge-sulphate of ammonia.....	56.17	15.1	1.66	68.4	.23	4.2
Check-nitrate of soda.....	74.90	3.4	.82	37.3	.05	6.0
Moss-nitrate of soda.....	46.19	12.1	1.64	93.8	.14	5.1
Sedge-nitrate of soda.....	54.92	15.5	1.85	74.9	.26	4.7

* Analytical data by I. C. Feustel.

The table shows the effects, in two years, of the different fertilizers on the acidity of the soil and mixtures of peat with soil. The urea check plot was distinctly acid, pH 4.6. The lime with the urea changed the soil reaction to pH 6.4 which is the least acid plot. The sulphate of ammonia changed the soil to a more acid reading of pH 4.1. The nitrate of soda reduced the acidity to a reading of pH 6.0. The peat made little change in the degree of acidity in the two sets receiving urea and sulphate of ammonia. Where the fertilizers used tended to correct the acidity the peat checked such changes. In these plots the peat was used in a 50-50 mixture by volume, so changes may be regarded as extreme for all practical purposes. It will be noted also in the table that the moss peat, which is ordinarily more acid than sedge peat and is supposed to have a more acidifying effect on soils, actually was far less effective than sedge peat in these tests.

In the above table the column headed "Loss on Ignition" represents the measurement of the organic content of the soil. It will be noted that the sedge peat produced a greater increase in the organic content of the soil than did an equal volume of moss peat. This column also serves to emphasize the fact that a large volume of peat is required to make any substantial change in the organic-matter content of the soil. These figures represent also the organic matter contained in the root systems included in the samples.

In the column of the table showing the maximum water-holding capacity of the samples it will be seen that there were large increases due to the addition of peat. In all cases the moss peat figure is larger than that for the sedge peat plots. The moss peat more than doubled the maximum water-holding capacity of the natural soil. It is interesting to compare these figures with those in the moisture con-

tent column, which show more moisture in the sedge peat mixture than in the moss peat.

The figures in the column of the table showing the total amount of nitrogen show approximately twice as much nitrogen in the sedge peat plots as in the moss peat plots, which in turn contained two and three times as much nitrogen as did the natural soil. All of the plots had received the same amount of nitrogen.

Selecting Peats and Mucks

The large assortment of peats and mucks that are available for golf course use serves to complicate the task of selecting the best and most economical types for any particular course. In some instances golf courses have paid good prices for peat materials which have been hauled in from distant points, while they have had in some out-of-the-way corner of their property an equally good grade of material in ample quantities that has been available simply for the cost of digging and handling. On the other hand some clubs have been using peat deposits found on their properties which, because of certain unfavorable characteristics, cost the clubs far more than would a good grade of commercial peat shipped hundreds of miles to the course. Before a wise selection of peat or muck can be made one should have an understanding of some of the fundamental characteristics of peats and mucks and should have at least a casual acquaintance with some of the factors that should be considered in comparing the relative values of different peats or mucks. The different types of peat are described and classified elsewhere in this number of the Bulletin.

The selection of peat for a golf course may be decidedly influenced by the use for which it is purchased. Peats have a lower content of decomposable constituents than many other organic materials such as manure, straw and vegetable matter in cover crops, and in this respect reed and sedge peat contain comparatively more residue that resists further decay than does moss peat. A coarse fibrous and even a woody peat, if available at a favorable price, may be used to advantage in the construction of a course where the material is to be thoroughly disced into the soil and the coarser particles will be left to undergo gradual decomposition. On the other hand, the same coarse or woody material is entirely unsuitable for mixture with soil for use in topdressing putting greens. Coarse material may be used in compost piles or soil beds with manure or with other fertilizers to aid in the decomposition, and after a sufficient time has elapsed these materials will provide the necessary organic component to make a suitable topdressing mixture. Many cases have been observed where golf courses in the interest of economy have purchased a coarse grade of peat containing a large proportion of woody fragments. This material before being used for immediate application to greens in topdressing material has to be sifted. The total bulk is greatly reduced when the coarser fraction is removed. The actual cost of the usable material obtained in this manner after deducting the cost of the discarded fraction and the cost of labor in removing it may be greater than that of material sold at a higher price. In purchasing peat, therefore, it is important to consider cost of the actual material that is usable for the special purpose for which it is purchased.

Peat and muck have large water-holding capacities. In compar-

ing prices of peats or mucks one should take into consideration the amount of water contained in each lot. In many cases golf clubs have purchased peat on a weight basis when as a matter of fact they have actually been purchasing largely the water obtained in the peat. When clubs buy fertilizers wisely they purchase on the basis of the percentage of nitrogen, phosphoric acid, and potash that the fertilizer contains. These three materials can not be obtained without obtaining some inert materials; likewise, in the case of peat, it is impractical to obtain the organic material without purchasing at the same time some water, because all the water can not be driven out of peat without destroying some of its important characteristics. Nevertheless, allowance should be made for the amount of water each sample contains.

Some peats and mucks contain substances that are toxic to plants. In some instances these toxic substances can be removed or converted by proper handling. Before any peats or mucks are extensively used on a golf course it is well to make sure that they do not contain any of these toxic substances. In some instances the excessive quantity of acids that may occur in peat may be detrimental to turf development. In some instances, particularly in California and certain other western states, deposits may contain alkalies which are decidedly detrimental to plant growth, particularly when added to soils which already contain too high a concentration of alkalies. Excessive quantities of iron or other elements or combinations of elements may occur in peats or mucks and make them unsuitable for turf use until such chemicals are removed.

In the experiments at the Green Section turf gardens no toxic materials were encountered in the peats and muck tested. At the Arlington garden, however, one of the samples of charcoal which was tested proved to contain sufficient toxic material to prevent the establishment of turf.

A set of plots was established for testing the effects of charcoal mixed with soil for turf production purposes. A surface layer four inches in thickness was prepared by mixing 50 per cent of clay loam soil with 50 per cent of granulated charcoal. Charcoal from different sources was used for the tests.

One of the plots containing charcoal failed to produce a stand of grass even when reseeded several times. Much of the seed germinated but the seedlings soon wilted and died. An examination of the soil showed that it contained excessive quantities of alkali. The toxic chemicals were traced directly to the charcoal. The amount of charcoal used in these tests was more than is ordinarily used on golf courses, but the excessive amount was used in order to bring out in a striking manner any advantages or disadvantages in its use. It is possible that the moderate use of this charcoal on a putting green would have given no such strikingly harmful results as was experienced on this plot. Nevertheless, a decided injury undoubtedly would have resulted from the use of even small quantities of this particular sample of charcoal. It was material that had been recommended by the manufacturer for golf course use, and probably much of it has been used on golf courses, where it no doubt has caused damage even though this damage may not have been recognized. The other plots containing other samples of charcoal showed no signs of injury and produced a turf equal to that produced in the adjoining check plots. In these tests there was no

evidence of the beneficial results that are so often claimed to be associated with the use of charcoal in soils for putting green turf.

Regardless of whether charcoal produces more beneficial results under certain conditions than has been observed at the Arlington turf garden, these results clearly indicate that whenever this material is used special precautions should be taken to avoid obtaining a charcoal that is a by-product of certain industrial processes which are apt to contaminate it with toxic chemicals which may be a detriment to turf and if used in sufficient quantities may entirely prevent any growth of grass.

In purchasing mucks one should make allowance for the amount of mineral soils contained in them. In adding these materials to soils the chief objective is to add organic material. Some of the muck that is purchased by golf clubs actually contains comparatively little organic material. It is chiefly clay or silt with a relatively small proportion of well-decomposed organic material. Where muck is used for the improvement of sandy soils there undoubtedly is some advantage in the addition of clay or silt together with the organic material to make a sandy loam soil. The relative difference in the cost of organic material and of clay or silt justifies a careful consideration of what proportion of the muck that is purchased represents organic material and how much of it is simply silt or clay. In some cases, particularly with some types of sedimentary peats or mucks, there apparently is little relative structural benefit derived from adding the material to plastic soils. In some instances a black soil is purchased under the assumption that it is peat, when in reality it contains no peat whatever and may actually be extremely deficient in organic material, for the black color may be due to mineral coloring. In the purchase of peats or mucks allowance should be made for the differences in weights for a given volume. Moss peat, which is poorly decomposed, weighs only 10 to 15 pounds a cubic foot; and peat varies from 20 to 35 pounds; cultivated and kiln-dried reed peats vary from 35 to 45 pounds; and sedge peat varies from 18 to 30 pounds to a cubic foot. These weights are influenced by the state of decomposition and the moisture content.

Suggestions for the Use of Peat on Golf Courses

It has been found that one of the most effective ways of using peat or muck on golf courses is to work it thoroughly into the soil before planting. This applies not only for turf purposes but also for use on flower gardens and for the planting of trees. For this purpose it is well to have the material shredded or pulverized and spread over the surface to the desired depth before plowing and discing thoroughly.

When using peat it usually requires the addition of about 15 to 30 per cent of peat by volume, depending on the organic contents of the soil and the peat, to bring the soil up to an organic content of approximately ten per cent. Observations and tests indicate that this amount of organic matter in putting greens is not too much, although somewhat less is probably sufficient for fairways, lawns, and flower gardens. If the soil is to be prepared to a depth of five inches a one-inch layer of peat should be spread and mixed with the four inches of underlying soil. It requires three cubic yards of material to spread a layer one inch thick over 1,000 square feet.

On some clay or silt soils the addition of 15 to 30 per cent of peat does not break down the stickiness or cohesion of the soil sufficiently, in which case the addition of sand may be made until the desired texture is reached. Seldom is it necessary, with the most compact of soils, to add more than one-third sand when the amounts of peat mentioned above are also added.

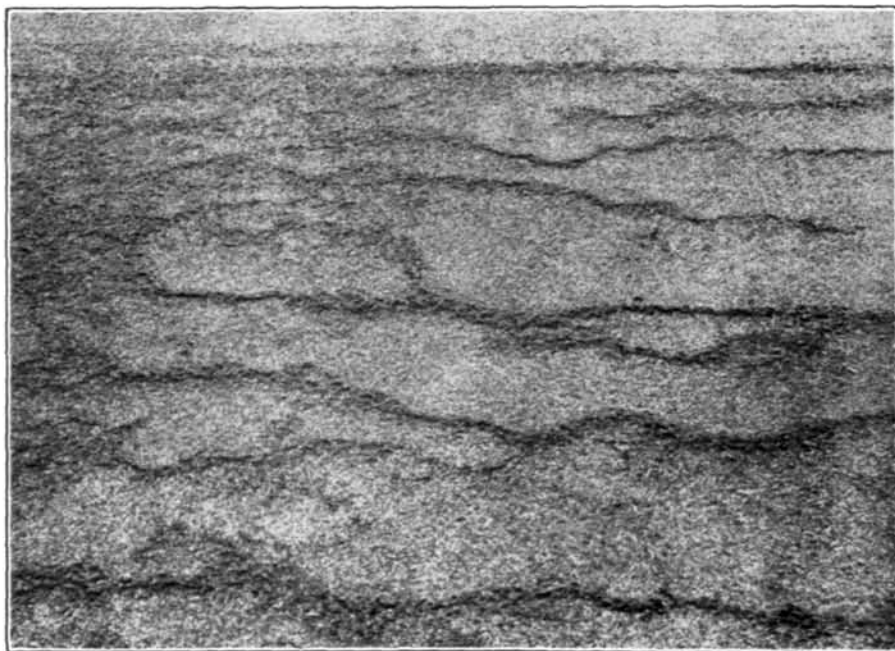


Use of sand and peat in improving the structure of a clay soil on the course of the Augusta National Golf Club. The area to be improved was first covered with a layer of sand (above) and this in turn was covered with a layer of peat (below). These layers were then thoroughly worked into the surface soil.

The layers of peat or peat and sand can then be thoroughly disced into the soil. Before the discing operation is completed it is well to add an ample supply of fertilizers containing phosphoric acid and potash and to apply lime wherever the soils are distinctly acid. These materials are not soluble and it is much better to work them into the soil rather than to apply them later when they remain on the surface for some time before reaching the plant roots. It has been found that it is worth while to take some trouble if necessary, in order to thoroughly mix the added layers with the soil and thus avoid any layers or pockets which may be decidedly detrimental to the turf in later years.

If the area is to be planted immediately the large moisture requirements of the peat should be supplied as much as possible by watering the area thoroughly a day or so before planting. Also, as the peat may reduce, for some time, the supply of available nitrogen to the plant, a good application of some organic nitrogen carrier should be mixed in the top inch or two of soil or soluble nitrogenous fertilizer should be raked into the surface just before planting. Later, the planted area should not be allowed to become too dry and should receive nitrogenous material whenever the plants show some signs of being starved.

If it is practical to do so, it will be found decidedly helpful in improving the soil structure in areas to be prepared in advance, or in preparing soil to remove elsewhere, to plant a cover crop on the land after the peat, fertilizer, and lime have been worked into the soil. This cover crop can be turned under and thoroughly worked into the soil. The addition of tops and roots of this cover crop will not only add further organic material to the soil, but will greatly stimulate the activity of microorganisms in the soil, which will be a distinct aid in getting the soil into good condition for the planting of turf.



Poorly decomposed peat is unsatisfactory for topdressing putting greens. The turf shown here had been topdressed with a mixture of topsoil, sand and peat. A heavy shower floated the peat out of the mixture and deposited it in ridges which were extremely difficult to remove.

Peat or muck is sometimes used in the pure form for topdressing putting greens, tees, and occasionally fairways. Such topdressings in time build up a soft, spongy surface layer which may be difficult to keep true for putting surfaces. Also on fairways or other areas

where the turf may be thin, topdressings of pure peat are usually unsatisfactory because of the tendency to wash and to form into ridges which interfere with the mowing and playing conditions. When used for topdressing putting greens, peat or muck should be used mixed with loam and sand. For most soils a satisfactory combination consists of one-third peat, one-third clay, or silt loam, and one-third coarse sand. Where possible, this mixture should have manure or other fertilizers added to it and prepared in a compost pile or in a soil bed for a couple of years to assure the proper breaking down of the coarser particles of peat. Peat, unless thoroughly decomposed, will float out of topdressing during heavy showers and accumulate in ridges, which will completely destroy the trueness of the putting surface. This condition is shown in the illustration.

Peat or muck can be satisfactorily used in compost piles and soil beds to add the necessary organic material to the soil. When using it in this manner the material should be used in conjunction with some fresh manure or should have added to it sufficient fertilizer and lime to aid decomposition. For more detailed information on the preparation of compost, the reader is referred to the September, 1930, issue of the Bulletin.

Organic matter is more effective in improving the physical condition of clay and silt soils than is sand, and if the organic matter of the pile is brought up to 15 or 20 per cent, the need for sand is cut down. Tests may be made to determine the exact mixture of soil, organic matter, and sand needed. Methods of testing are described in the Bulletin for February, 1932. It usually requires the addition of at least 50 per cent, by volume, of organic materials to make the percentage of organic matter in the pile as much as 15 or 20 per cent after it has undergone some decomposition. This is because the organic content of soils is figured on a dry-weight basis, and many organic materials, such as manure, clippings and other vegetable refuse, and some peats, contain as much as 50 or 60 per cent of moisture.

Manure, clippings, and the organic matter in sods frequently break down so quickly that very little is left by the time the compost is ready for use. Peats, however, strongly resist further decomposition and tend to keep up the organic contents of the compost even though the compost has been well heated. It is desirable to have a certain amount of manure in compost piles to create bacterial action, but the manure may be replaced by at least 50 per cent of peat. Peat alone may be used in the pile, and some organic nitrogen carrier such as a sewage sludge, cottonseed meal, or a pulverized poultry manure may be used to aid decomposition and heating of the pile. The inclusion of 5 to 10 per cent, by bulk, of these materials is usually sufficient.

Using Peat or Muck Deposits Found on Golf Courses or Near-by Property

The Green Section frequently receives samples of peat or muck representing deposits found on golf courses or somewhere nearby and which represent materials that can be obtained at a low cost. These samples may prove to be high-grade materials quite suitable for the purpose in mind. Many of the samples, however, are of little or no value, and if used, would undoubtedly do more harm than good. Therefore, before one utilizes any local materials it is well

to make sure that the deposits under consideration are suitable for turf-culture purposes.

As a general rule, the first step in the utilization of a local peat deposit should be to drain it adequately by means of open ditches or by tiles. When the deposit is drained it is well to plow it and keep it in cultivation for at least a year. The area can be well fertilized and limed when necessary and can be planted with a cover crop or some cultivated crop. This process of cultivation should last at least a year and preferably two or three years, and then the top layer to a depth of two or three inches can be removed and stored for further use.

Material that is obtained in this manner from local deposits can be used for mixing in soil or for the preparation of topdressing material just as has been suggested above for the use of commercial peats.

Toll from Plant Diseases—The average mind can hardly conceive of the enormous loss sustained in the United States from plant diseases. The plant pathologist in charge of the plant-disease survey of the Bureau of Plant Industry, reports that \$1,500,000,000 annually is lost in this country alone and that losses in other countries are proportional. Plant diseases are of three classes—nonparasitic, parasitic, and virus diseases. Nonparasitic diseases are caused by unfavorable environment, condition of soil, or air or mechanical influences, but are not contagious or infectious as is the case with the parasitic diseases. Parasitic diseases are caused by the attacks of living organisms, plant and animal, and may be transmitted from plant to plant by a transfer of the agent. The exact cause of virus diseases has not been determined, but these diseases are increasing rapidly and have assumed considerable importance among the plant diseases of the world.

Control methods, such as preventing the introduction of diseased plants into the country, the eradication of the disease, quarantine of states and territories, and the selection and development of plant varieties which will resist the attacks of the diseases, are used to combat their spread.

The development of a strain of grass which will resist the attacks of dollarspot, brownpatch, spotlight, snowmold and the other turf diseases seems to be the solution of the disease problem with respect to golf course turf. In addition to its resistant qualities, the strain must of course have the necessary requisites of good turf. Until such a turf has been tried, proved, and accepted, we must use such control methods as are now in general use if we are to have desirable greens.

The migratory locust of northern Africa, western Asia, and eastern Europe is a large, long-winged grasshopper that flies in swarms so vast as to darken the sun. When a swarm settles on a field or orchard it often wipes out every trace of green leaf and stem in 15 minutes or less. Fortunate it is that golf courses in the United States are troubled with insects no more voracious than the Japanese beetle, June beetle, May beetle, mole cricket, and a few others.