Soils, Their Composition and Fertility

By PROFESSOR C. E. MILLAR,

Michigan State College, Lansing, Michigan

Reprinted from address delivered at the Annual Greenkeepers Educational Conference in Chicago

MANY soil troubles experienced by groundskeepers are prepared for him before the course comes under his supervision. The desire to reduce construction costs results in the considerable use of whatever soil material is at hand, whether it be suitable or unsuitable. The foundation is thus laid for continuous trouble with ultimate reconstruction unavoidable so that the final total cost is far in excess of what the cost of proper construction in the beginning would have been, not to mention the inconvenience, worry to the greenkeeper and Green committee, and the criticism by players.

C. E. MILLAR

Who has practically every kind of soil in Michigan and understands all of them.

This idea is admirably expressed in the following quotation from Professor Dickinson: "On many of the younger courses (5 to 10 years old) the greens are failing physically because of hurried, careless, and low-priced construction."

I would not have you think, however, that the greenkeeper may lay all of his trouble at the door of faulty construction and then go blameless. He, as everyone else, makes mistakes and must take the consequences.

Men differ in personality and disposition. If you are to live harmoniously with your fellow men, you must take into consideration these differences in your dealings with them. Likewise, greens differ in their characteristics and you must consider these differences in your management of them. This idea is very aptly put in the following quotation from a recent editorial by Mr. Robert E. Power in the NATIONAL GREENKEEPER, "The greenkeeper knows his soil condition, his climatic condition, his exposures, his particular problems on every one of the 18 holes of his course. They are not all alike and if he treats them so, he is no credit to the profession."

It is not my purpose, therefore, to outline any specific procedure or to give any specific advice but rather to call to your attention some fundamental facts which may be of assistance to you in outlining your management program.

In the beginning let us examine the soil situation on a green. No condition could be more artificial than that existing in greens soil. It is watered copiously at frequent intervals, yet it must not get soggy. Above all, it must not dry out. It must hold ample water but not too much. The green is submitted to constant tramping, yet it must not get packed or hard. Neither must it be too springy. The soil must supply ample nutriment to support a luxuriant growth of grass, yet the diet must be balanced so as not to result in weakened vegetation, subject to disease attack and breakdown under unfavorable climatic conditions.

What manner of soil possesses all these qualities? First there must be a substantial framework to support the load but with plenty of space between the supports. For the main units of the frame we depend on sand, and sand of fair size, not fine sand. The intermediate members of the structure should be of organic matter or humus. This material gives a measure of elasticity, thus preventing packing. The remainder or filling material may be of silt with some clay and fine sands.

POROSITY MUST BE MAINTAINED

POROSITY must be maintained at any cost in order that excess water may escape easily and air enter freely. This point was stressed by John Anderson in his recent article. Many troubles may be traced to lack of porosity, many more in fact than can be attributed to excessive porosity. Many greenkeepers bemoan the fact that their soils are too sandy,

but they are much better off than the man who has to deal with heavy binding soil.

The kind of soil the foundation of a green is constructed of does not make a great deal of difference so long as a suitable thickness of surface soil is used. In various parts of the country we find greens with foundations of clay, or pure sand, or even of rocky material, and yet supporting fine turfs which are kept in excellent condition with very little trouble. On the other hand, you are all familiar with greens built on clay or sand which are always sources of worry to greenkeepers. The difficulty usually lies in an insufficient thickness of suitable surface soil. In making these remarks I am assuming that the conformation of the green permits of ready escape of excess water or that pockets are adequately tiled.

It is not an impossibility to maintain a good turf on greens having an insufficient thickness of surface soil or having surface soils containing too little or too much clay and humus. To maintain a satisfactory turf under such conditions, however, requires constant watching, much good judgment on the part of the greenkeeper, and infinite care in watering. Some excellent ideas on watering and drainage were brought out by President MacGregor in his recent article.

A reasonable percentage of clay in greens soil is desirable because the clay gives substance or consistency to the soil. It is the safety valve or regulator. It takes up plant food when an excess is present and gives it off when the supply is low. It has shock-absorbing qualities—buffer capacity we call it—that is, it resists change.

THE DIFFERENCE BETWEEN CLAY AND SAND

THE difference between clay and sand in their ability to resist change, that is, chemical change, may be crudely illustrated as follows: Let us suppose two barns, one having stalls for 24 cattle and the other for six cattle, are full of cattle. Now if six cattle are taken from each barn the one is empty while the other still contains 18 head and many cattle may still be supplied from it. On the other hand if both barns are empty and it is desired to get a herd of cattle in out of a storm, one barn is full when six cattle have been placed in it while the other barn is only one-fourth full when six cattle are in it. In other words, one barn is easily emptied or filled while the other, having much more capacity, resists filling and emptying to a much greater extent.

Now how does this apply to soil in a green? Suppose sulphate of ammonia is added to the green. The clay will immediately take up considerable quantities of the ammonia and gradually give it off later as the supply in the soil moisture is exhausted. A soil composed largely of sand will hold very little of the ammonia, however, allowing it to be carried away in the drainage water. Again, suppose some acid-forming material as aluminum sulphate or sulphur is added to the soil. A soil containing clay will resist the acid-producing effect and will be made only slightly more acid. On the other hand a soil composed largely of sand does not have the capacity to resist change and hence will be considerably increased in acidity.

Organic matter or humus also has some buffer capacity or resistance to change, but it is quite small compared to that of clay. On the other hand, very finely divided humus, similar to clay in size, does have a large capacity to take up and give off soluble plant food.

CHEMICAL CHANGE IN SOIL PARTICLES

AT FIRST thought one is inclined to consider soil particles as simply rock fragments of various sizes. This conception is probably true for the sand particles and to a certain extent for the larger silt particles. As the smaller silt particles and clay come under consideration we must, however, recognize that a considerable chemical change has occurred in addition to a reduction in size. The basic constituents, that is those substances or elements which have the power to sweeten or neutralize acids, are dissolved from the surface of the particles. This loss together with other chemical alterations results in the formation of a jelly-like substance which exists as a coating on the surface of the small particles. In fact the finest particles undoubtedly consist very largely of a sticky, jelly-like material which is the product or residue of the chemical breakdown of the original mineral fragments.

It is this gelatinous substance which gives clay its stickiness and causes it to shrink and get hard when dry. The ability to take up plant food elements and

hold them in reserve is also due to the activity of this glue-like material. The buffer capacity, or capacity to resist change is due to the presence and activity of this substance.

It is evident that a certain amount of this stabilizing material is desirable in a greens soil. On the other hand, too much of it is very objectionable, as you all know from experience. I might also remark that a little of this glue-like or colloidal material goes a long way. So dominant is it in imparting its characteristics to a soil that if 30% or even less were present you would all characterize the soil as a heavy clay.

The value of humus in the soil has been stressed by Mr. Williamson in his articles in the NATIONAL GREENKEEPER. Earlier in this paper I referred to the importance of humus or organic matter in giving resilience to the soil. Whether or not this valuable function is performed depends to a considerable extent on the nature of the organic matter used. Organic matter of a sticky, gummy nature, frequently found in sections of the country where muck beds occur, is not suitable for use in making surface soil for greens. Such material shrinks excessively when drying, becomes soggy and compact with tramping and in no way imparts to the soil the elasticity and porosity that is desirable.

Organic matter should be more or less fibrous to give to the soil the properties desired. If decay has proceeded to such an extent that the fibrous nature of the material is entirely destroyed it should not be used.

ABOUT TOP DRESSINGS

THE properties of a desirable top dressing soil are identical with those required of a good surface soil for as time goes by the top dressing material constitutes the upper section of the surface soil. This statement raises the question of whether or not different greens do not require top dressing of different quality. For example, should a green constructed of soil containing an excess of clay be top-dressed with soil composed largely of sand? I am well aware that there will be wide differences of opinion on this point.

You will agree, I think, that the sand should not be used in such a manner as to ultimately form a layer of virtually pure sand in the green. The detrimental effects of such a layer are familiar to all. If the sand could be thoroughly incorporated with the soil there would be no question of the advisability of its use. Whether or not this end can be accomplished without tearing out the green and rebuilding it is a question which can be answered only by careful trial.

The use of top dressing soil unusually rich in humus and sometimes clay has been advised on greens composed of very sandy soil. The same general criticisms may be made of this practice that were raised regarding the use of sand on heavy soil.

On the whole it is doubtful if much can be done in the course of two or three seasons to alter the texture of the soil after a green has been constructed. In general it may be better to use a soil of desirable qualities composed of proper proportions of sand, clay, and humus, regardless of the nature of the surface soil.

AUTHOR TESTS SOIL SAMPLES

THE question now arises as to what is the make-up of a desirable top dressing soil. To obtain an answer to this problem the writer procured samples of the top dressing soil being used by a number of quite

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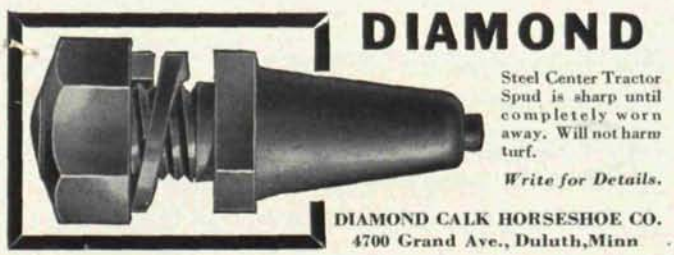
successful greenkeepers in Michigan—and, by the way, we have some mighty good greenkeepers in Michigan. These soil samples were taken to the laboratory and submitted to an analysis to determine their stickiness and the percentages of sand, silt, clay, humus, and water-holding capacity. The results are submitted in the following tables:

TABLE I

Soil No.	Humus %	Sand %	Clay %	Silt %
1	1.5	63.6	16.5	15.2
2	2.4	85.4	5.7	8.1
3	2.5	78.8	5.5	13.0
4	4.2	80.1	9.3	11.0
5	6.8	63.8	14.2	16.0
6	8.6	72.3	11.0	9.9
7	15.0	61.5	6.8	15.9
8	16.0	66.7	7.4	9.1
9	16.5	57.3	7.0	19.6
Average	8.1	69.9	9.2	13.0

The first point that attracts our attention in these analyses is the great variation in the percentages of humus in these soils. You will note that they are arranged in ascending order in regard to humus content. The variation, therefore, is from 1.5% in soil No. 1 to 16.5% in soil No. 9.

Now, why this wide difference in humus content? It is not because of a lack of available humus, because the first five samples come from sections of the State where ample humus in the form of muck and peat is easily obtainable. The answer must be, therefore, that these five greenkeepers consider the percentages of humus in the soils they are using best adapted to the needs of their greens. In the case of soil No. 2, I chance to know that the soil from which the greens are made is very heavy and the greenkeeper is endeavoring to improve aeration and drainage by using a spike disk and applys a very sandy top dressing. You will note that his soil is the most sandy of any, having a total sand content of 85.4%.



The greenkeepers using the last three soil, 7, 8, 9, evidently consider from 14 to 16 per cent humus more desirable than 8 per cent or less, at least for the greens on the courses they are managing.

It is noteworthy that the percentages of sand run from about 60, 57.3 to be exact, to 85.4, with only one sample exceeding 80%. There is evidently much closer agreement as to the desirable percentage of sand than of humus for while soil 9 contains eleven times as much humus as soil 1, soil 2 only contains about one and one-half times as much sand as soil 9. Very presently we will examine the sand in these soils more in detail to get an idea as to how coarse the sand should be.

CLAY SEEMS TO BE DESIRABLE

THE percentages of clay in these soils indicate that these greenkeepers appreciate the value of a reasonable percentage of this material. Soil No. 1 deserves attention. You note that even though it is very low in humus it is also one of the lowest in sand content but is the highest in clay and contains a goodly percentage of silt. I will venture that this soil is fairly sticky and gets decidedly hard when dry. It is my opinion that the continued use of this soil will lead to difficulty.

As might be expected the percentages of clay vary much more than the percentages of sand but are much more uniform than the percentages of humus. The average percentage of clay, omitting soil No. 1, which is quite unusual, is 8.36. You will recall that I have referred to clay as the stabilizing component in soil, that is, the material which gives it buffer capacity. A reasonable quantity of clay is highly desirable but clay is so potent in impressing its characteristics on a soil that more than a moderate percentage is to be avoided.

Considerable variation in the silt content of these soils is not surprising. Silt has little stickiness when wet and yet it is not friable and porous as is sand. It adds body and considerable firmness to a soil without the danger of sogginess or hardness. With a reasonable percentage of humus, considerable silt is desirable in a green's soil but in combination with any large quantity of clay and especially with a low humus content it is dangerous since it tends to accentuate the clay properties. In general I would say that if the humus content runs below 9 or 10%

the clay and silt content should not exceed 25 or 30% unless there is more silt than clay.

STICKINESS OF SOILS

THE stickiness of these soils in relation to the percentages of clay and humus present should prove an interesting study. This data in addition to the percentage of maximum available water retained is presented in table 2.

TABLE II

Soil No.	% Clay	*Stickiness	% Humus	% Maximum Available Water
1	16.5	12.7	1.5	28.8
2	5.7	2.4	2.4	24.5
3	5.5	0.0	2.5	37.3
4	9.3	2.4	4.2	34.0
5	14.2	0.0	6.8	36.2
6	11.0	0.0	8.6	30.2
7	6.8	0.0	15.0	55.3
8	7.4	0.0	16.0	72.8
9	7.0	0.0	16.5	50.6

*Pounds per 10 square inches at one-half maximum available water content.

It will be observed that soils 1, 2, and 4 are the only ones exhibiting any stickiness at one-half the maximum available water content. The stickiness of soil No. 1 is outstanding as was predicted from its clay content in conjunction with the meager quantity of humus. The percentages of clay in soils 2 and 4 though not large are sufficient to give a slight stickiness because of the small humus contents of the soils. The efficiency of humus in overcoming the tendency of clay to make soils sticky is well illustrated in soil No. 5. Despite the comparatively high clay content of this soil it exhibits no stickiness even though it is one of the lowest in total sand content.

Considering the low humus content of soil No. 3 in association with a clay content virtually equal to that of soil No. 2 the question arises as to why this soil does not exhibit a slight stickiness. The answer may be found in the percentage of silt which is 13.0 as compared to 8.1 per cent in soil No. 2.

HUMUS AND CLAY HOLD WATER

THE influence of humus and of clay in increasing the capacity of soils to retain available water is well set forth in this table. The high clay content of soil No. 1 in combination with the 15.2% of silt give this soil a very appreciable water-holding capacity despite the fact that it contains a negligible quantity of humus. The capacity of humus to impart water-holding power to soils is well illustrated by a comparison of soils 1 and 4. With little more than half the clay content of soil 1, soil 4 holds 5% more water due undoubtedly to its higher humus content, which nevertheless is very low for a topdressing soil.

The high water-holding capacity of soil No. 3 immediately attracts attention in view of the low percentages of clay and humus. The very high content of very fine sand, 35.2 per cent in association with 26.1 per cent of fine sand undoubtedly accounts for the water-retaining power of the soil.

The tendency of fine and very fine sand to increase water-holding capacity of a soil is again illustrated in soil No. 8. In this case 37.2 per cent of fine sand and 23.4 per cent of very fine sand in conjunction with 16.0 per cent of humus give the soil the enormous water-holding capacity of 72.8 per cent. Soil No. 9 with slightly more humus retains only 50.6 per cent of water because it has only a moderate percentage of fine sand as will be seen from table 3. Tables 2 and 3 should really be considered at the same time, and I will call attention to some of these points once more as we study table 3.

Now let us turn our attention to the dimensions of the sand particles found in these soils.

TABLE III

Soil	Total Sand	Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand
1	63.6	0.6	8.1	24.8	22.1	8.0
2	85.4	3.4	12.8	38.2	24.4	6.6
3	78.8	1.0	3.7	12.8	26.1	35.2
4	77.8	5.3	32.5	33.2	6.3	3.7
5	63.8	0.9	3.7	22.4	30.9	5.8
6	72.3	1.8	3.5	20.9	28.2	17.9
7	61.5	2.6	6.1	16.7	23.2	13.0
8	66.7	0.9	1.0	4.2	37.2	23.4
9	57.3	2.0	4.6	12.1	18.4	20.3

A glance at this table shows there is no uniformity in the size of the sand in the different soils. The percentage of fine gravel is small in all cases as it should be. It is noteworthy that with the exception of soil No. 3 the percentage of very fine sand is appreciable only in the soils containing the greater quantities of humus (Soils 6-7-8-9). Possibly this is a coincidence since the sand may have been associated with the humus in the natural state and not added to the compost as sand. At least the point is significant.

Very fine sand has a great tendency to pack in between the particle of larger size thus making a hard soil quite impervious to water and decidedly undesirable in a green. This point will be emphasized very presently in another table. The high water-retaining capacity of soils No. 3 and 8 as related to their high content of fine sand and very fine sand was referred to a few moments ago. Humus will prevent the packing tendency of very fine sand, hence the advisability of having a high humus content if much very fine sand is present.

FINE SAND NEEDS LOTS OF HUMUS

FINE sand has a less propensity to pack than very fine sand but still any considerable quantity of it is undesirable unless associated with a high percentage of coarser sand or with humus. Soil No. 3 is open to much suspicion because of its high content of very fine sand, and fine sand, moderate content of medium sand, and low percentages of coarse sand and humus. This soil contains only 2.5 per cent of humus, you will recall.

Soil 4 might be criticized for its high percentage of coarse sand together with a large quantity of medium sand. I could not agree with this criticism. If soil 4 had 10% or more of humus in place of 4.2% and somewhat more than its 9% of clay and 11% of silt it would make a very desirable soil in my opinion.

To illustrate the undesirable properties of a soil containing too much of the finer sands and silt without adequate humus, I present the analyses of samples taken from two greens, one of which is always in good condition and the other a constant trouble maker.

TABLE IV

Green	Humus	Total Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt	Clay
P—Surface	6.1	68.5	1.0	8.6	28.4	29.9	17.2	14.3
G—Surface	9.3	56.2	1.7	8.3	20.2	25.5	28.3	14.3
P—Subsoil		84.4	1.4	24.7	39.3	18.9	10.1	7.0
G—Subsoil		88.3	7.4	22.1	42.2	12.5	6.2	5.6
P—Subsurface		59.2	0.3	0.5	27.0	29.6	24.0	13.7

You will note from table 3 that the surface soil from the poor green (P) contains 3% less humus than that from the good green (G). This soil, however, contains 12% more total sand, slightly more fine sand and very fine sand but decidedly less silt. The clay content is identical. On the whole there is not sufficient difference in these two soils to account for the vast and constant differences in the quality of the turf.

The subsoil from the poor green is somewhat heavier, that is, richer in very fine sand, silt, and clay, than that from the good green and yet it is sufficiently porous to permit of adequate and rapid drainage. Just below the surface soil in the poor green, however, occurs a layer containing a total of 80.6 per cent fine sand, very fine sand, and silt, each constituent occurring in well above 20%. There is virtually no medium sand, coarse sand, and humus to ameliorate the condition. This layer is very compact and impervious, preventing the escape of excess water and requiring infinite care in watering. This green is an example of attempted economy in construction and to my mind will ultimately have to be torn out. Proper construction in the first place would have been much more economical.

TOP DRESSINGS ARE ALL DIFFERENT

IN CONCLUSION let me call attention to the fact that a study of the physical characters of the top-dressing soils used by nine grenekeepers show a very great variation in humus content. There is more uniformity as to the total percentage of sand but much difference in the size of the sand present. The percentages of silt and clay vary in such a manner as to lead one to feel that the quantities present are more or less a matter of hit or miss and not of intention.

Possibly these soils are designed to meet some particular condition prevailing on the various courses. None of these greenkeepers, however, mentioned the use of different soils on different greens, and we must assume that the soils presented are being used on all the greens. It is scarcely to be expected that all the greens on a course will have the same defect although such a situation is entirely possible.

All points considered these soils must be accepted as meeting the various greenkeepers' ideas of good topdressing soils. Does it not seem to you that there should be more uniformity of opinion among representative greenkeepers as to what constitutes a good soil?