Principles of Soil Preparation for Drained Golf Greens

by **L. ART SPOMER,** Associate Professor of Plant Physiology in Horticulture, University of Illinois, Urbana

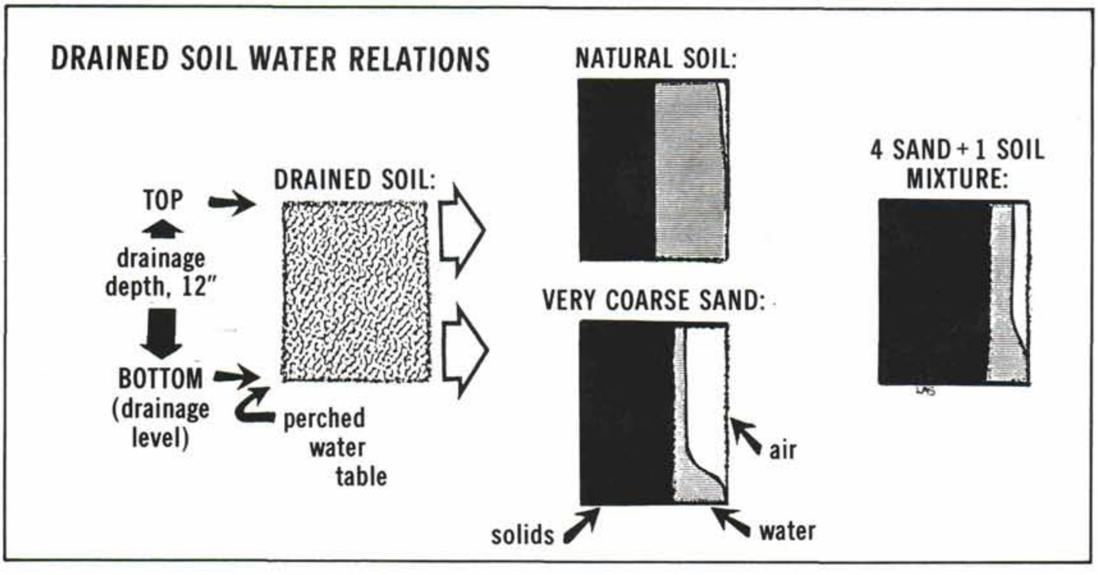
INTRODUCTION

Plants grow by accumulating raw materials (carbon dioxide, water, minerals, and energy) from their environment. Our cultural practices for golf green turf maintenance are therefore oriented toward providing an optimum supply of raw materials to the turfgrass community.

In relation to these cultural practices, the plant and its environment may be divided into above ground (shoot and aerial environment) and below ground (root and soil environment) portions with the growth of the whole plant depending upon the interaction between them. Shoots absorb energy (light) and carbon dioxide while roots absorb water and minerals. The turfgrass shoot is well-exposed to its energy and carbon dioxide supply; however, the root exists in a relatively unfavorable supply environment where replacement of absorbed water and minerals near the root's surfaces occurs very, very slowly. Plants therefore have evolved tremendously extensive root systems which often have over a hundred times as much surface as the shoot (even though the shoot may actually be two or three times heavier than the root). The development of an extensive, functioning root system is therefore essential for proper turfgrass growth and survival.

The proper development and functioning of turfgrass root systems necessitate an adequate soil environment. Unfavorable soil environmental factors will inhibit root development and functioning. Many biological, chemical, and physical factors directly and indirectly affect plant root growth and function. These factors affect either soil water retention and movement or plant root growth and function. The most important soil physical factors directly affecting plant water absorption are soil water content and soil aeration. Water content, the amount of water in the soil, is important because it directly indicates how much water is potentially available for plant use and indirectly how tightly it is held in the soil. Soil aeration, the exchange of oxygen and carbon dioxide between the soil and above-ground atmospheres, is important for maintaining a constant supply of the oxygen required

Figure 1. *Drained golf green soil water relations. A perched water table forms at the bottom of the soil (drainage level) and any soil in the green will be saturated at the bottom. Most natural soils are saturated throughout their entire depth following drainage. Very coarse-textured materials such as sand are saturated at the bottom and dry at the top. An ideal green soil is a compromise between these two extremes and is achieved by mixing sand (or other amendments) with soil. The amounts of solids, water, and air in natural soil, very coarse-textured sand, and a mixture of soil and sand are illustrated in this diagram.*



for good root growth and absorption. Soil water content and aeration both depend upon the amount and size distribution of the soil pores which, in turn, depend upon the size and packing of the soil particles. We can therefore control the physical environment of the soil by controlling soil porosity with special soil mixes.

This article briefly considers the principles for optimizing the golf green soil physical environment through the use of soil mixes.

DRAINED GOLF GREENS

Drained golf greens are different from other golf course turf sites, and they therefore must be backfilled with special soil mixtures during construction in order to avoid excessive water retention (poor aeration) and compaction. The relatively shallow drainage and heavy traffic on these drained greens render natural soils unsuitable for these sites. The purpose of these special media is to insure the proper balance between water retention and aeration through control of the pores.

Most drained golf greens have two important features which distinguish them from other golf course turf sites: (1) they are subject to severe foot and mower traffic and (2) they are drained. The effects of the traffic are obvious (soil compaction, poor root growth and absorption); however, the effects of the shallow drainage (excess soil water content and poor soil aeration) are less obvious but are generalized in *Figure 1*. A perched water table forms at the bottom (drainage level) of a drained green soil following irrigation and drainage. Any media in such a site will be saturated at the bottom and water content will decrease with height above the bottom. Almost any medium of fine-textured natural soil will be saturated throughout its entire depth and grass growing in such natural soils will likely suffer from poor aeration. At the other extreme, a very coarse-textured medium will have excellent aeration but will retain insufficient water for growth, especially when the plants are young. The main difference between these two media is that the soil contains primarily small, water retention pores which remain water filled under the influence of the water table, whereas the sand contains primarily large aeration pores which drain despite the water table at the bottom. An optimal medium for a drained golf green would be a compromise between these two extremes. It is usually attained in practice by mixing very coarse-textured amendments such as sand, calcined clay, perlite, etc. with soil in order to provide sufficient large aeration pores while at the same time retaining sufficient water retention pores to insure adequate growth.

SOIL AMENDMENT: SOIL PHYSICAL CHANGES

Soil or root growth media suitable for turfgrass growth in drained greens are therefore prepared by amending soils. Unfortunately, too little amendment reduces both soil aeration and water retention without increasing the soil's resistance to compaction. Too much amendment reduces water retention excessively. The optimum amount of soil amendment should maximize soil compaction resistance while at the same time provide soil aeration and soil water retention which closely match those required for good turfgrass growth and water absorption.

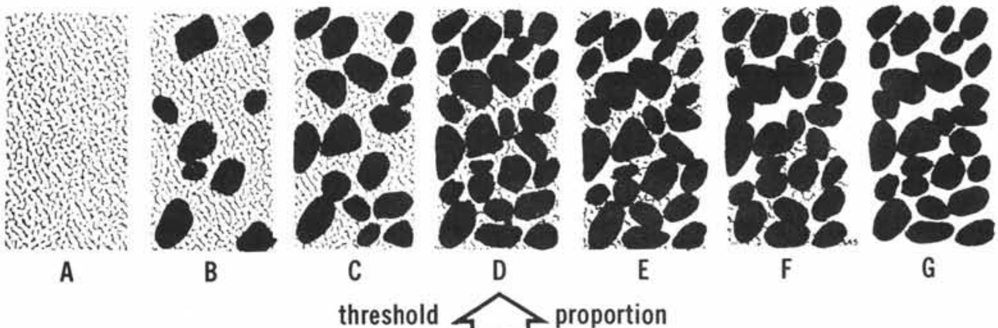
Figure 2 pictures what happens as a coarse-textured amendment is mixed with soil in increasing proportions. Beginning with 100 per cent soil, mixture porosity first decreases, then increases

Figure 2. *Effect of increasing amounts of amendment on soil porosity. The sand is a very coarse-textured river sand and the soil is a silty clay loam. Mixture component proportions are shown as mixing or bulk volumes. Mixture total bulk volume was kept constant.*

Effect of Amendment on Soil Porosity

AMOUNT OF SAND, SOIL & PORES (yd^3 in ten yd^3 mixture)

	A	B	C	D	E	F	G
soil ➧	10.	7.7	5.5	3.6	2.5	1.5	0.
sand ➧	0.	3.5	7.	10.	10.	10.	10.
pores ➧	5.	3.9	2.8	1.8	2.4	2.9	3.6



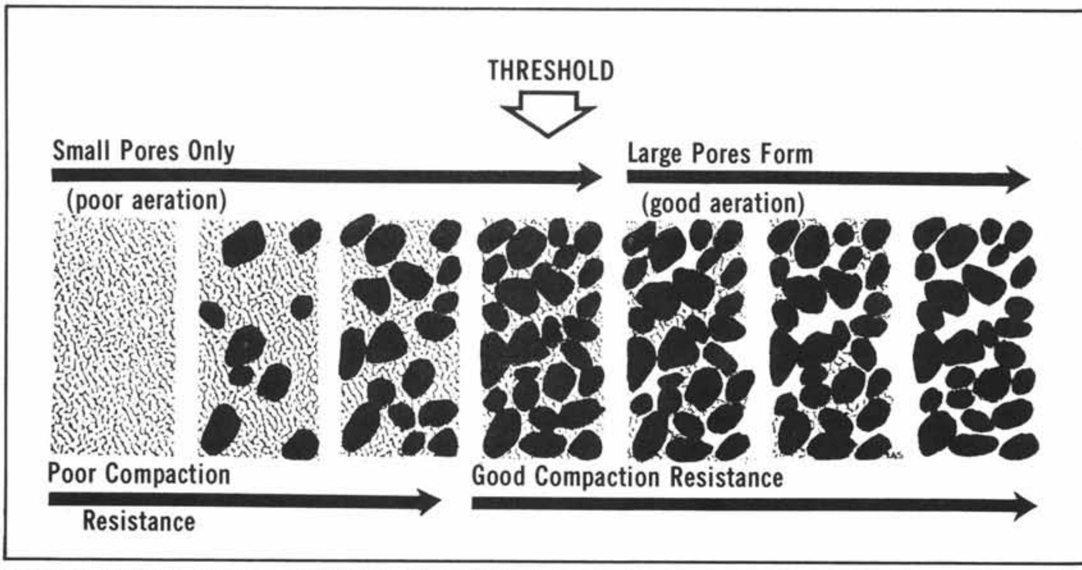
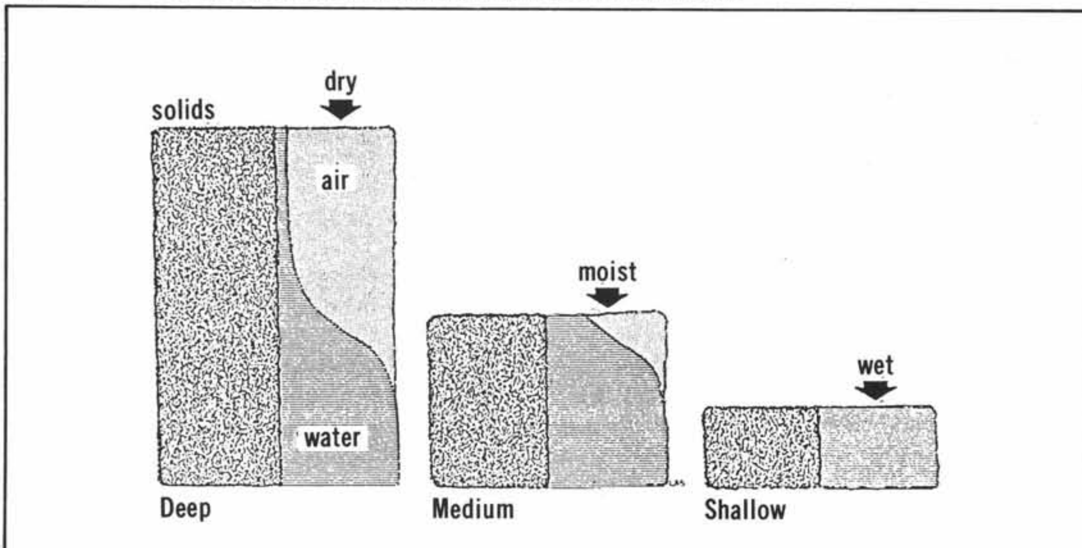


Figure 3. *Pictorial diagram generalizing the effect of increasing amounts of amendment on soil porosity, water retention, aeration, and compaction resistance (see Figure 2).*

with the addition of amendment in increasing proportions. Porosity initially decreases because the amendment floats in the soil or excludes soil solids and porosity without adding any large amendment pores (A, B, C). The minimum porosity occurs at the threshold proportion (D), which is the mixture in which the green excavation is exactly full of amendment and the large pores between the amendment particles are exactly full of soil. In other words, the threshold proportion is determined primarily by the amendment's interporosity (porosity between the particles). This mixture is called the threshold proportion because it delimits the minimum proportion of amendment required before further amendment begins to improve soil aeration. Total porosity is at a minimum at the threshold and aeration porosity is still nonexistent, so this is the worst possible soil mixture for plants. The threshold proportion is an excellent mixture for making a path, roadbed, adobe house, or earth-

Figure 4. *The effect of amendment particle size on water retention in a drained golf green. The amendment was a river sand which was sieved to obtain the various particle size fractions (USDA classification). Only the very coarse-textured sand and coarse-textured amendments would be suitable materials for drained golf greens (usually about 25 to 30 centimeters deep). The dashed line indicates the water retention of the original (unsieved) sand (which has about 6 per cent less total porosity).*



fill dam, but not for golf greens. Because the amendment particles also first exhibit particle-particle contact at the threshold, this mixture also delimits the minimum amount of amendment required for good compaction resistance. As the amendment proportion is increased above the threshold (E, F, G), aeration pores are emptied of soil and aeration and total porosity both increase. Looking at this in another way, at and below the threshold (A, B, C, D), amendment particles merely occupy volume in the green without adding any porosity. All we have done up to the threshold proportion (A, B, C, D) is reduce the soil volume (water and nutrient storage) without adding aeration, so any amount of amendment below the threshold worsens the soil physical environment. At and above the threshold proportion (D, E, F, G), the small soil particles fill in the large pores between the amendment particles to varying degrees. This effect of soil amendment on porosity and aeration is summarized in *Figure 3*.

The threshold proportion is the minimum amount of amendment which must be added to soil before any improvement in aeration can be expected. The threshold proportion depends on amendment particle shape and, to a lesser extent, size. It is directly related to the amendment porosity (about 25 to 35 per cent for most sands, 35 per cent for calcined clay and perlite). For a sieved sand or medium grades of calcined clay or perlite, the threshold proportion is about 10 volumes of amendment mixed with 3½ to 4 volumes of soil. A safe mixture for a drained golf green should therefore be about 10 volumes of sieved amendment (no fines) mixed with 2 to 2½ volumes of soil. If the fines have not been washed or sieved out of the amendment, a safe mixture for drained golf greens would be about 10 volumes of amendment mixed with about 1 volume of soil. Organic amendments such as peat, bark, and others generally require less amendment to reach the threshold proportion. Such amendments, however, are also less stable and tend to decompose or change with time and therefore may not be desirable for use in a golf green.

This picture of what happens when we amend soils is not a new concept; however, it has only recently been put into a potentially useful form for mixing soils on the golf course. In the past, golf green soil mixtures were developed through inefficient soil trials in which plants are grown in a series of media containing different proportions of various components. A simple mathematical and graphical model is being developed at the University of Illinois which can be used to produce mixtures having specific, predictable properties (total porosity, aeration porosity, water retention porosity). In other words, it is possible to control the soil physical environment in a predictable manner through the use of soil mixtures.

CONCLUSION

This article does not recommend any specific golf green soil mixture; rather it briefly describes what happens when an amendment such as sand

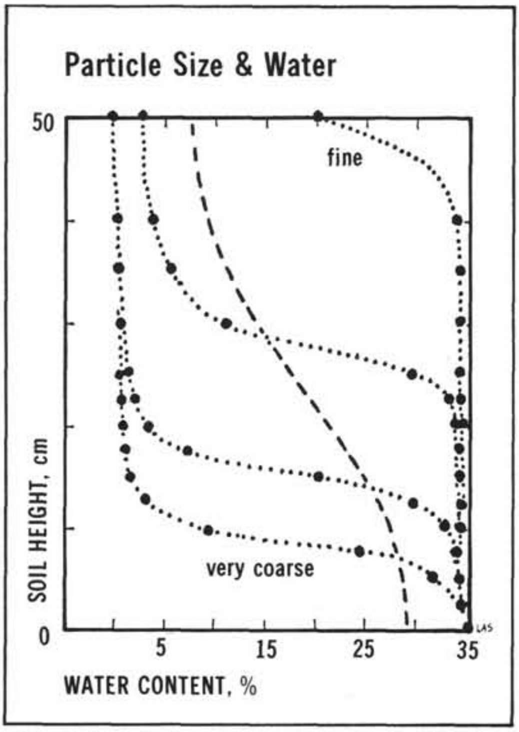


Figure 5. *The effect of drainage depth on the water retention of a very coarse-textured sand. The only difference between the three soils is their depth. A shallower drained green will always be wetter following irrigation and drainage than a deeper green using the same soil mix.*

is added to a soil. The take-home lesson is that drained golf greens are different from other turf sites and therefore require special soil mixes to maintain an adequate soil physical environment for continued root growth and function. Unless these mixes are designed properly, the results can be worse than if the original site soil is used. A certain minimum amount of amendment, the threshold proportion, is required before soil physical improvement is effected and this amount is usually quite high (75 to 90 per cent or more of the total bulk volume of the components). The optimum soil mixture depends on soil, climate, drainage depth, and plant species and is therefore difficult to determine without professional assistance and previous experience under similar conditions.

Not only is the amount of amendment important, but also the kind of amendment (primarily size) (*Figure 4*) and drainage depth (*Figure 5*). Other important factors are the length of time the green is in place, the effect of thatch and topdressing on the rootzone environment, and the chemical nature (pH, nutrient holding capacity, decomposition, etc.) of the amendment and soil used in the mixture. These effects are not entirely understood, but are currently under study by the USGA Green Section and others.