price, discountable field, and 9 freight levels. The price and freight amounts are keyed from the accounts receivable master.

With the file interaction chart (see Fig. 1), we can see the modular relationship that this system has. It provides us with the ability to change as our business changes. It allows us to address a particular problem unique to a particular nursery, plant, size, area or customer. It assists us in determining how effective our salespeople are, how profitable our customers are, what customers are buying and when they are buying. It provides us with plant cost by size, by variety and by square foot.

These are our tools. With proper utilization by management this system can assist you in procuring a bright future. I've enjoyed presenting this topic to you and will attempt to answer any questions that you have.

Physical Amendment of Landscape Soils*

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Introduction

Land•scape (land'scap)—To improve the appearance of (an area of land, a highway, etc.), as by planting trees, shrubs, or grass, or altering the contours of the ground. **[The Random House College Dictionary]**

As this definition indicates, the 'ground' is the foundation for the landscape, and in most sites, the 'ground' is soil. The suitability of the soil making up the ground is, therefore, fundamental to landscape construction. It is judged by the soil's capability to sustain plant growth and by the landscaper's ability to construct and maintain desired topographic features with it. Soils are often physically unsuitable for these functions or are rendered so by construction or subsequent use. Unsuitable soils can often be improved by the addition of various chemical and physical materials.

Sand is probably the most commonly used physical amendment for landscape soil although various other organic and inorganic materials are also frequently used. Unless properly used, physical amendments may not benefit the soil and can actually worsen it. What constitutes proper use depends on the nature of the original soil; the nature of the amendment; and the purpose for which the soil and site are intended.

This paper briefly discusses the objectives of soil physical amendment and describes what happens to a soil's physical properties when it is amended with sand or other physical amendment.

What is Soil?

Before discussing physical amendment, we should first examine the soil's physical properties. What is soil? Ask ten different soil scientists and you are likely to hear ten different answers—all correct! Since landscaping is a practical activity, soil, for our purposes is probably best defined in relation to its uses in the landscape. From the plant's point of view, soil is any solid material in which it can grow and which will sustain its growth. This functional definition covers a wide range of materials used in horticultural practice. Although most landscape soils are natural, some horticultural soils (potting mixes in particular) are not even recognizable as soil unless we actually see them used as soil.

Regardless of their composition, all soils consist of solid, liquid, and gaseous components. The soil solid component consists of particles and is called the soil matrix (see Fig. 1), and the liquid component consists of water and dissolved materials including mineral nutrients and is called the soil solution, and the gas component consists of the same gases as above-ground air and is called the soil atmosphere. Although the soil solution and atmosphere directly affect plant growth, whereas the matrix usually does not, the nature of these two components is largely controlled by the soil matrix. The soil matrix is therefore the most important physical part of the soil, overall, and is the part that we change, or try to change through physical amendment.

The matrix is the soil's foundation or framework and determines its overall physical character and suitability for plant growth and other landscape functions. It consists of minute, solid, inorganic and organic particles packed together into a semirigid, spongelike mass. The spaces between the particles form an interconnected tunnel-like network of soil pores permeating the soil mass. The pores are the single most important soil physical feature because roots grow in them, and water, air, and minerals are stored in and move through them. The nature of the pores also largely determines soil stability and resistance to compaction.

What is Required of Landscape Soil?

In order to sustain the plant, the soil must provide water, minerals, aeration, support, anchorage, and an otherwise adequate root growth environment. In most soils, water and aeration are the most critical factors; too much water retention (resulting in poor soil aeration or poor drainage) or too little water retention are common problems in landscape soils. Water retention is determined by the nature of the soil pores. Small pores tend to retain water and impede drainage, while large pores tend to provide aeration and facilitate drainage.

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An ideal landscape soil maintains a balance between water retention and aeration to ensure an adequate water supply to the plant and sufficient aeration for root growth and function.

Landscape soils also often require stability to ensure the permanence of constructed features and support for structures. These attributes are determined by the 'rigidity' and structure of the soil (namely, particle grouping or aggregation) or stability and resistance to compaction. The latter condition and lack of stability are probably the most common landscape soil problems, especially in new construction sites and areas receiving heavy use (walkways or paths, athletic fields, golf greens, and so on). Compaction pushes soil particles closer together, reducing bulk volume, porosity, and pore size. A compacted soil usually exhibits poor drainage or puddling and poor aeration. Resistance to compaction is determined by the soil pore system, texture, structure, and water content. Both total pore volume, or porosity and pore-size distribution are important characteristics determining the soil's suitability for landscape purposes. The size distribution (soil texture) and type of soil particles are the major factors affecting the nature of the pore system and its stability and resistance to compaction. Finer-textured soils having high porosity and smaller pores tend to remain wetter and are less stable and more succeptible to compaction than are coarser-textured soils.

A landscape soil must have a suitable pore system to enable it to support plant growth or be stable for other landscape purposes.

When Should Physical Amendment be Used?

Physical amendment can be used to improve the soil's physical properties in most cases where poor aeration, poor compaction resistance and drainage result from poor physical properties. It can also be used where such problems are likely to arise during subsequent use. All these conditions depend on the nature of the pores. Physical amendment can be used to improve drainage and compaction resistance by creating large aeration pores and a stable soil framework and also to reduce porosity and drainage in the construction of pathways, roadbeds, ponds, etc. by plugging up or eliminating the large aeration pores.

Physical amendment is used to improve poor soil physical conditions resulting from a poor soil pore system. The main purpose of soil physical amendment is to change the nature of the soil pore system (including porosity, and pore size distribution by altering soil texture) to make the soil more suitable for the use for which it is intended.

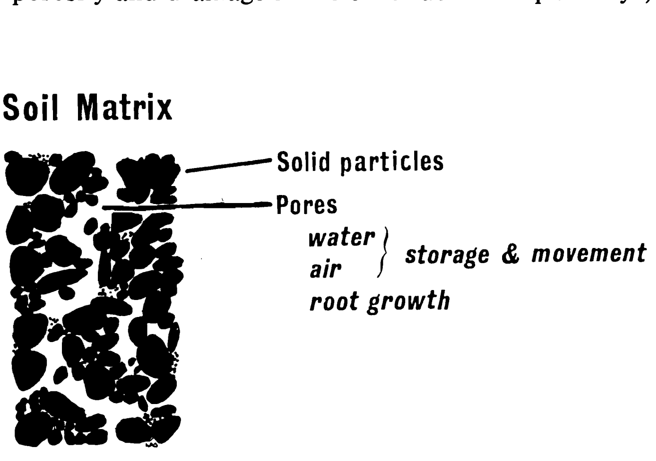

Fig. 1. Much enlarged depiction of a typical soil matrix, a spongelike mass consisting of minute particles and permeated by a network of pores in which water, air, and minerals move and are stored for plant use. The nature and arrangement of these particles determine the nature of the soil's pore system and its overall suitability for plant growth.

What Happens When Soil is Physically Amended?

The physical effect of amendment will depend on the amount of amendment added and the original composition and character of the soil. What happens when amendment is added? Figure 2 shows the effects of adding amendment to soil in increasing proportions.

In 100% soil (A), we find that all pores are small, and the soil is likely to retain excess water resulting in poor aeration and inadequate compaction resistance. The addition of a small amount of amendment (B) does not improve this situation. In fact, the amendment's solid volume merely excludes or displaces soil without otherwise changing the soil's physical properties relative to plant growth or landscape use. Therefore, soil total porosity, water retention, drainage, and aeration decrease in direct proportion to the amendment solid volume. Since solid volume in the amendment in this case is about 65 percent of its total or bulk volume, the addition of a given bulk volume of amendment will displace a soil volume and porosity equal to approximately 65 percent of the amendment's bulk volume. Amendment continues to be added (C) until it eventually reaches the threshold proportion. At the threshold proportion (D), the mixing volume (10 cubic yards) is exactly full of amendment, and its pores are exactly full of soil. Consequently, total porosity is at a minimum. This mixture has porosity similar to concrete and is the worst possible soil medium in which to grow plants. It does, however, make excellent runoff channels, canal beds, pond bottoms, pathways, roadbeds, earthfill dams, or other sites requiring maximum stability and resistance to compaction and minimum drainage into the soil. Instead of improving soil suitability for plant growth, drainage, and compaction resistance, the addition of less than the threshold proportion of amendment actually worsens these physical features.

As the sand proportion increases above the threshold (E,F,G), large amendment pores (aeration pores) are voided and total porosity, aeration, and drainage all increase, but water retention usually decreases. In other words, at and below the threshold (A,B,C,D), amendment particles merely occupy space in the soil volume without improving it physically. Above the threshold (E,F,G), the soil particles fill the large pores between the amendment particles to varying degrees. These effects of physical amendment on soil porosity, water retention, aeration and compaction resistance are summarized in Figure 3.

Although the example used herein involves sand and soil as the coarse and fine textured components, this same effect is observed whenever any coarse and fine material are mixed (i.e., coarse sand and fine sand, peat and sand, bark and sand, etc.).

Effect of Amendment on Soil Porosity

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

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

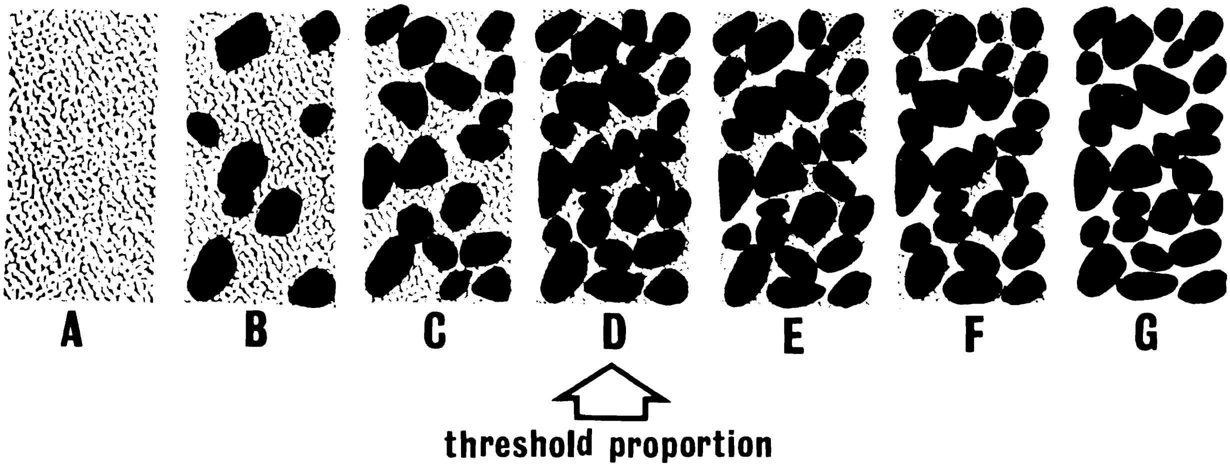

Fig. 2. The effect of mixing increasing proportions of very coarse-textured river sand with a silty clay loam soil (little or no sand content) on porosity. Total mixing bulk volume remains 20 cubic yards; the volume of pores is listed above the enlarged diagram of each mixture. Mixture A is 100% soil and mixture G is 100% sand. Note that the original individual component volumes, in B,C,D,E, and F do not add up to equal 10 cubic yards because the soil fills in the large sand pores.

Remember, the addition of insufficient amendment to achieve the threshold proportion actually worsens the soil's physical properties.

How Much Amendment is Necessary?

The amount of amendment required depends on the purpose for which the soil is being amended and the character of the soil and amendment. If it is to improve tilth (to make the soil easier to dig or cultivate), a relatively small amount is required. If it is to improve stability from compaction, enough must be used to completely fill the mixing volume (to achieve the threshold proportion) so the amendment will have direct particle to particle contact and provide an incompressible framework for the soil. For a roadbed, pathway, earthfill dam, or canal bed, you should add back enough soil to approximate the threshold proportion (to fill completely the large amendment pores). This situation results in minimum porosity and maximum compaction resistance and stability. The most suitable soil mixture for this purpose has the least possible porosity. Porosity can be reduced to less than 5 percent by mixing more than two particle sizes (i.e., gravel-coarse sand-fine sand-soil) together in the proper proportions, as is often done in highway construction. A seedbed or other site for plant growth or compaction resistance requires large pores that drain water and insure sufficient aeration. Less soil than the threshold (more amendment than the threshold) is required in this case. The threshold proportion is the key to determining how much amendment is needed. The only possible improvement resulting from less than the threshold proportion of amendment being added is perhaps an improvement in tilth, which is not likely to be an important soil characteristic in landscape sites anyway.

The threshold proportion is primarily determined by the amendment's interporosity (that between particles); but, also depends on the amount of coarse particulate already in the soil (all of the coarse material needs to be considered in determination of the threshold proportion). The proportion of soil at the threshold is that required to exactly fill the amendment interpores, the amount of which varies with the amendment. For example, sand porosity can be as low as about 27 percent for rounded particles (river sand), or even lower in sand containing a mixture of fine and coarse particles. The highest porosity in sand is about 40 percent for crushed or fractured and washed sands (contain little or no fine particles). The threshold proportion for sand or sandlike particles (i.e., perlite, calcined clay, etc.) is usually therefore approximately 10 volumes of sand mixed with 3.5 volumes of soil. In other words, if the mixing volume (final mixture volume) is completely filled with sand (100 percent), then soil totaling about 30 percent of that bulk mixing volume should be added to produce a suitable landscape soil for plants. Therefore, a good plant-sustaining, amended soil consists of about 10 volumes of coarse or very coarse material mixed with about 3 volumes of soil.

The amount of amendment required depends primarily on the nature of the amendment and secondarily on the amount of coarse material already in the soil.

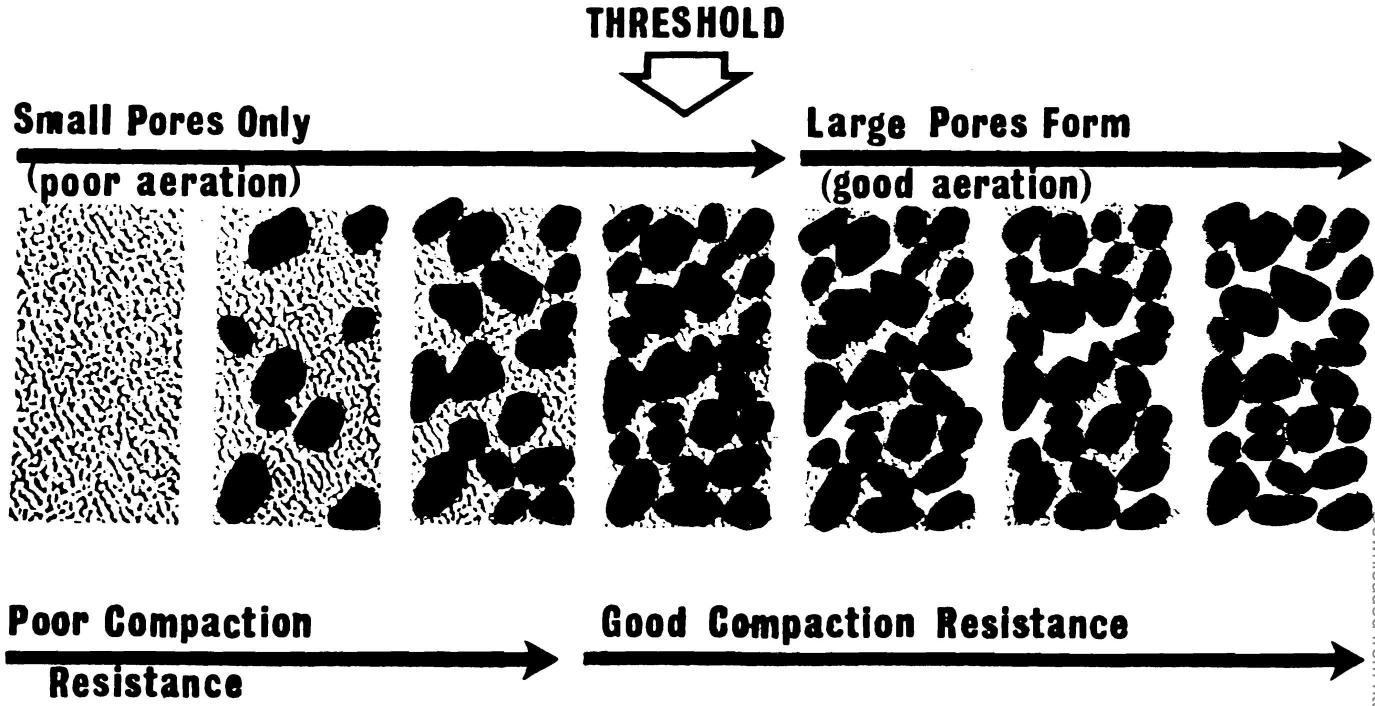

Fig. 3. Summary of the effects of soil physical amendment on soil pores and aeration. Small pores retain water in most soil sites. Aeration and drainage in poorly-drained soils will improve only when sufficient amendment has been added to form large aeration or drainage pores. Less amendment than this actually worsens soil physical suitability.

What is a Good Amendment?

The choice of amendment is usually determined by availability and expense. However, a monodisperse material (one having a single particle size) is usually superior to a well-graded material (one having a mixture of particle sizes) since the smaller particles tend to fill in or clog aeration and drainage pores and reduce water retention, rendering the material less efficient as an amendment. Inorganic materials tend to be less efficient amendments than organic materials, but the latter may stimulate natural aggregation and promote long term soil improvement even though they decompose with time.

Clean, uniform material is probably the best choice for landscape soil physical amendment.

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