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Soil Compaction and Free Pore Space

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All of us realize the importance of soil breakdown in regard to aeration and often refer to a soil as being "tight" or "well aggregated." We attempt to increase and stabilize aggregation of our soils by adding various materials (such as peat moss and sand) to a basic field soil. This increases the amount of air (free pore space), reduces resistance to root growth, and supposedly reduces the danger of deficient aeration. In Agronomic terms, the degree of consolidation (compaction) is evaluated in terms of "bulk density." Bulk density (BD) is expressed as grams per cubic-centimeter (g/cc) and is obtained by removing an undisturbed, known volume of soil and determining the weight of that sample after removing the water by drying.

In Table 1, we have compared under standard conditions, 4 soil mixtures. Note as bulk density increased, porosity (total pore space) decreased, and the most noticeable change was a reduction in air content. Moisture content was very similar in 3 of the mixtures, but was markedly greater in the Soil.

Table 1. Air and water content, porosity and bulk density of 4 media dried to a soil moisture tension of 64 cm of water. Each figure an average of 6 determinations.

Medium[a]	% by volume Air	Water	Porosity %	Bulk density g/cc
P-P	50	26	76	0.13
1-1-1 PM	27	28	55	0.93
1-1-1 LM	24	26	50	1.04
Soil	7	39	46	1.21

[a] P-P—Equal parts by volume peat moss and perlite.
1-1-1 PM—Equal parts by volume Eel silt loam, sand and peat moss.
1-1-1 LM—Equal parts by volume Eel silt loam, sand and leaf mold.
Soil—Eel silt loam plus ¼th sand.

Very few field soils may be found with bulk densities near 0.13 g/cc. Field soils usually have values between 1.1 and 1.5 g/cc. As a general rule, bulk densities in excess of 1.7 cause unsatisfactory growth, which results both from deficient aeration and because roots cannot penetrate the soil.

Table 2 indicates the rate of consolidation that may occur in a greenhouse bench when we fail to initiate preventative measures. These data were obtained from soil plus ¼th sand plots of various depths, in which two crops of snapdragons were grown. The soil was steam-pasteurized at the start, and irrigated overhead by Gro-hose. Comparisons between depths are difficult since the deeper the plot, the dryer the soil. However, comparisons between Crop 1 and Crop 2 at any one depth show the effect of increasing bulk density. That is, as aggregation breaks down, the amount of air present decreases. This was especially true in the 3 and 5 inch depths, which were the wettest treatments. In other treatments, where the root medium contained peat moss or leaf mold increases in bulk density during the growth of 2 crops were very slight.

Table 2. Comparison of air and moisture content and bulk density between 2 crops of snapdragons, grown consecutively in an overhead irrigated soil, (Eel silt loam plus ¼th sand). Each figure a mean of 6 determinations.

Depth of soil (in.)	Volume (%) Air Crop[a] 1	Air Crop 2	Water Crop 1	Water Crop 2	Bulk density g/cc Crop 1	Bulk density g/cc Crop 2
3	5	0	45	52	1.10	1.31
5	14	2	38	37	1.06	1.20
7	13	10	33	34	1.07	1.08
9	19	12	30	30	1.05	1.11
12	20	15	30	30	0.99	1.06
18	19	18	32	26	1.04	1.05
24	22	18	27	23	1.03	1.09

[a] First crop benched September 4, 1961
Second crop benched March 14, 1962

The method of applying water plays an important role in controlling the consolidation rate. Figures 1 and 2 compare air and water contents in a 1-1 mixture of peat moss and perlite (P-P) and an Eel silt loam plus ¼th sand (Soil). Both of these mixtures were irrigated overhead by Gro-hose. The data represents average values obtained during growth of 2 crops of snapdragons. In the wettest soil treatment (10cm water tension), free pore space was almost non-existent (Figure 1) as compared to a value of 30 percent for peat perlite at the same tension (Figure 2). In contrast, was the situation indicated in Figure 4 where

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identical root media were subirrigated by a constant water table. The wettest soil (soil–plus ¼th sand) treatment had a free pore space of about 10 percent versus 2 for overhead watered (Figure 1). The peat perlite, subirrigated treatment showed a slight increase in free pore space when compared to overhead irrigation (36% versus 31% in Figures 2 and 4). Changes in bulk density in this case were insufficient to account for the change in free pore space.

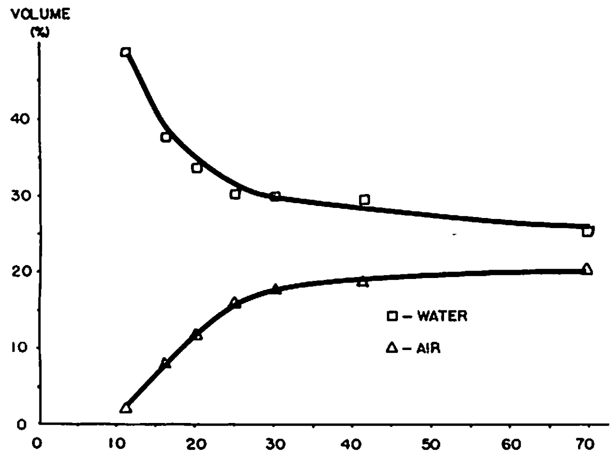

Figure 1. Overhead irrigated soil (Eel silt loam plus ¼th sand) showing air and water content when maintained at various moisture tensions.

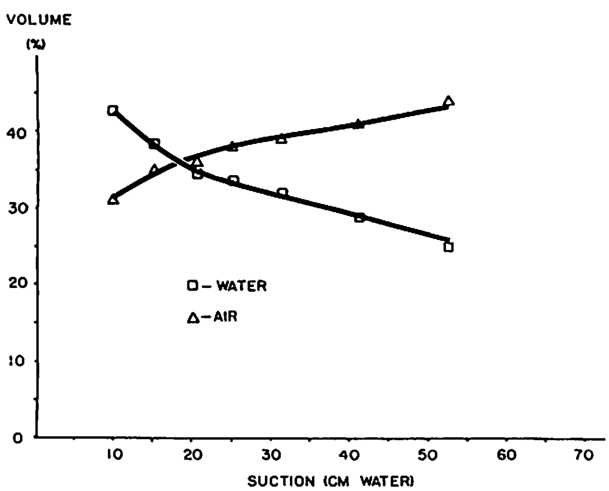

Figure 2. Overhead irrigated P-P (equal volumes of peat moss and perlite) showing the air and water content when maintained at various moisture tensions.

Figure 4 shows air and moisture relationships that occurred in a 1-1-1 mixture of soil, sand and peat moss when subirrigated. The addition of peat moss to the soil, which decreased bulk density, increased the air content (approx. 10%) while moisture content was only slightly reduced.

If the air and moisture content for overhead irrigated 1-1-1 PM, as presented in Figure 3, are compared with the soil-plus-sand medium in Figure 1; the amount of water remaining in the soil at a particular soil moisture

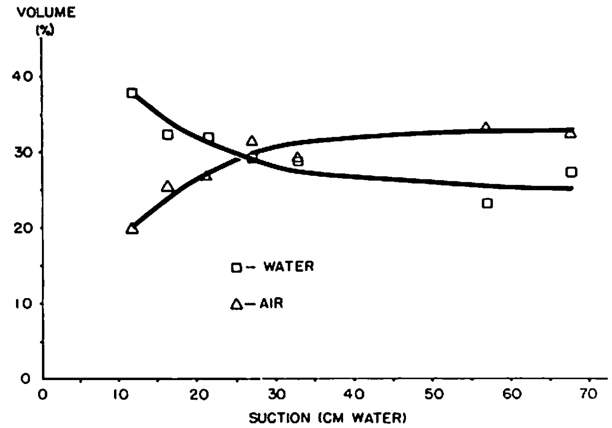

Figure 3. Overhead irrigated 1-1-1 PM (equal valumes of Eel silt loam, sand and peat moss) showing the air and water content when maintained at various moisture tensions.

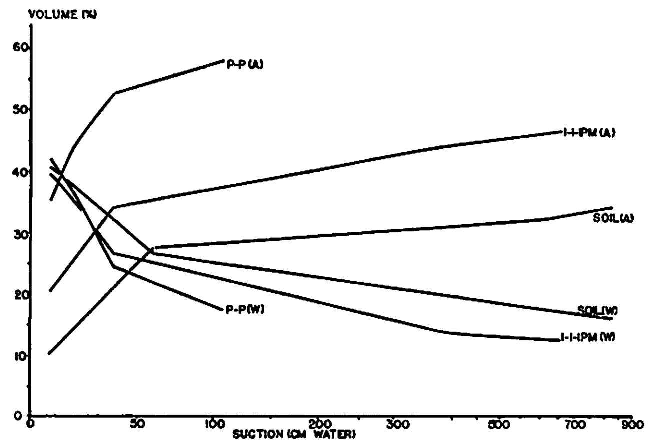

Figure 4. Subirrigated Soil, PP and 1-1-1 PM, showing the air (A) and water (W) content when maintained at various moisture tensions.

tension was less for peat moss. Thus, adding peat moss or leaf mold not only increased free pore space, but also reduced the amount of water that remained.

Summary

1. As compaction (bulk density) increases, the total pore space (porosity) decreases, and the amount of free pore space is markedly decreased.
2. The relationship of the amount of air and water to the total porosity is dependent on the wettness of the soil and the soil mixture.
3. If proper precautions (such as the addition of peat moss to the soil or other similar materials) are not taken, compaction will increase rapidly with successive crops.
4. Overhead irrigation generally reduces free pore space to a greater degree than subirrigation.
5. The addition of peat moss, leaf mold, etc., to a soil not only increases porosity, but in contrast to common belief, reduces the amount of water retained. In other words, peat moss does not increase the water holding capacity of a soil.
6. A word of caution should be introduced. It would appear that mixtures similar to the peat-perlite studied here would be eminently suitable, however, other prob-

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lems enter in. It has been our experience that very wet peat-perlite mixtures usually result in poorer growth than soil containing media at similar moisture contents—despite air contents of 30 percent or more. Thus, the use of bulk density and amount of free pore space as criteria for evaluating aeration are not always reliable. They are just part of the picture.