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PHYSICAL PROPERTIES AND LEACHING RATES OF ROOT MEDIA

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Studies on different root media and soil-sand combinations in 8-inch deep layers resulted in these general observations:

1. It was not a good practice to add fine sand to a heavy clay soil. The result was increased weight and reduced percolation, total pore space and water storage capacity.
2. Some amendments, such as finely ground peat moss and fine manure did not greatly increase percolation rates, even when the final ratio of the mixture was 1:1 amendment-soil.
3. Adding two amendments so that the final ratio was 1:1:1 was usually sufficient to significantly increase percolation rates, total pore space, and reduce weight.
4. Some amendments such as pine bark and almond hulls, in a 1:1:1 ratio with soil, so increased percolation rates and reduced capillarity as to make them very difficult to adequately wet, particularly with trickle irrigation systems.
5. The ability to remove salts from a shallow mixture in this study was unrelated to the amount of water passed through it. High percolation rates were not proof that a mixture can be easily leached.
6. The amount of water required to remove 100% of the salts was not related to the mixture's water holding capacity.
7. The rate of leaching, assuming the surface was flooded, was directly related to the concentration at which leaching was started. That is, it was easier to leach a soil starting at a high concentration as contrasted to a low initial salt concentration, particularly if the mixture had a high percolation rate.

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Methods

A series of root media were made with local materials (Table 1), consisting of almond hulls, sheep manure and shredded pine bark. Imported German peat moss was included. A second series used a heavy clay loam with different proportions of sand as an additive. Fertilizer was added to these mixtures prior to planting.

A sample of each mixture was taken, moistened, and allowed to equilibrate for at least 24 hours in sealed metal cans. Following equilibration, each mixture was poured into 1¾ x 10 - inch plastic cylinders and packed by dropping the cylinder several times on a hard surface. The final depth of all columns was 8 inches. Each mixture was set up with 5 different columns. After packing, each column was wetted to drainage and allowed to sit for 24 hours. A constant head of ½-inch water was maintained on the surface of each column, with leachate collected from the bottom at regular intervals, and the salts determined by measuring the electrical conductivity of the leachate. After 30 minutes to one hour, the percolation rate of each cylinder was measured 3 times. When the salt readings of the leachate had approached a value nearly equal to the water applied to the surface (about 670 μmhos/cm), the water was shut off and the cylinders allowed to drain. After drainage, the soil was weighed, dried and re-weighed. From these data, moisture content, total pore space, air space and bulk density were calculated.

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Table 1: Root media description.

Number	Abbreviation	Volumes	Description
1	S-PM	1:1	Soil and peat moss
2	S-B	1:1	Soil and bark
3	S-AH	1:1	Soil and almond hulls
4	S-M	1:1	Soil and sheep manure
5	S-PM-B	1:1:1	Soil, peat moss and bark
6	S-B-AH	1:1:1	Soil, bark and almond hulls
7	S-M-B	1:1:1	Soil, manure and bark
8	S-M-AH	1:1:1	Soil, manure and almond hulls
9	S-PM-AH	1:1:1	Soil, peat moss and almond hulls
10	PM-B-AH	1:1:1	Peat moss, bark and almond hulls
11	S-Sa(?)	— —	Basic clay loam with an unknown amount of sand, used in mixtures 1 through 9.
12	S(clay loam)	— —	Basic clay loam from the field
13	S-Sa(10%)	1:9	Clay loam with 10% sand
14	S-Sa(30%)	3:7	Clay loam with 30% sand
15	S-Sa(50%)	1:1	Clay loam with 50% sand
16	S-Sa(70%)	7:3	Clay loam with 70% sand
17	S-Sa(90%)	9:1	Clay loam with 90% sand
18	Sand	— —	Sand

Results

Physical properties:
Mixtures containing some organic material were much more variable in regard to percolation, moisture content and bulk density than a clay soil to which sand had been added. Mixtures 1 through 10 were, therefore, statistically analyzed separately from the soil-sand combinations (Table 1). Also, there appeared to be differences based upon whether the final combination was a 1:1 ratio versus a 1:1:1 ratio, a pure soil, sand or a soilless mixture (No. 10). The mixtures were broken in 6 groups and analyzed separately (Table 3).

Thus, it was noted that adding sand to a clay loam in amounts less than 70% of the final volume usually reduced percolation rates, maximum moisture content and total porosity (Table 2, Fig. 1). When these mixtues were removed from the cylinders and dried, the sand appeared to increase "cementing". From the standpoint of total pore space, air space and water content, the basic clay loam was a more desirable medium than almost any combination of soil and sand.

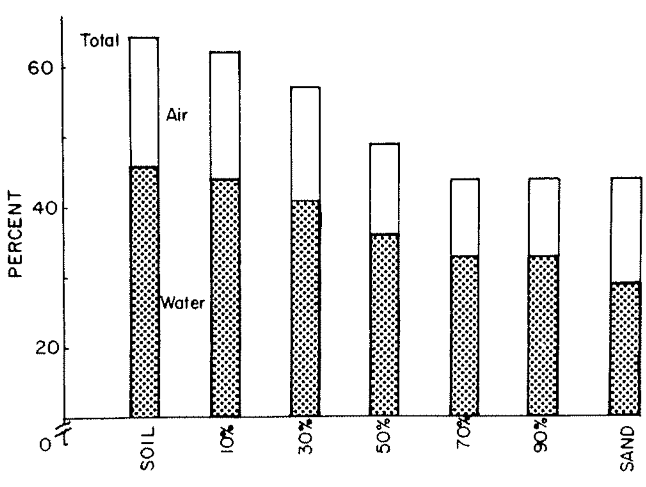

Fig. 1: Graphic representation of moisture holding capacity, air-filled pore space and total porosity of different clay loam-sand combinations.

Certain organic amendments at a 1:1 ratio with soil and an unknown amount of sand had relatively low percolation rates (peat moss and manure). The large size and uniformity of almond hulls resulted in a relatively low percolation rate and a heavy medium (55.5 lbs/cu. ft.). When the final proportions were 1:1:1, however, most parameters were increased significantly with soil-almond hulls-bark (No. 6), soil-manure-almond hulls (No. 8) and the soilless mixture, bark-peatmoss-almond hulls (No. 10), having the highest percolation rates. Quite literally, water could be poured through these mixtures, and observations indicated that capillarity was so reduced that a single trickle emitter was insufficient to adequately wet 3 gallon pots in which plants were established.

Leaching rates:
As would be expected, the relationship between salt removal and time, where the soil was flooded, was curvilinear. Leaching was at first rapid, gradually becoming slower as the salt concentration in the soil approached that of the applied water (670 µmhos/cm) (Fig. 2). By converting time to logarithms, it was possible to mathematically calculate straight lines that fitted the data with high correlations exceeding 0.90 and often more than 0.95 (perfect is 1.00). One rather startling result of this exercise was the fact that the slope of each curve (rate of decrease) was determined more by the salt concentration at which one started than by the mixture itself (Fig. 3). If the rate of leaching was plotted against initial concentration of the leachate, a straight line resulted which said, in effect, leaching rate could be determined if one knew the starting point. If the slope (rate) was known, the time required for leaching could be predicted. This did not say anything about the amount of water required.

From the data on leaching rates, and the percolation of the mixtures when flooded, Table 4 was prepared to show the time and amounts of water required to achieve 50, 75 and 100% salt removal. One thing was immediately apparent, the amount of water retained by an 8-inch column and the amount of water required to leach had no apparent relation to the leaching rate. Invariably, if the percolation rate increased, the amount of water required, under conditions where the mixture was flooded, increased. Leaching efficiency became quite low.

Table 2: Some physical properties of different soil mixtures.

Number	Description[z]	Bulk density (lbs. per cu.ft.)	Percolation rate[y] (gal per min per sq.ft.)	Moisture content[w] (%)	Specific gravity[v]	Total pore space[u] (%)
1	S-PM	40.5	0.29	45	2.64	75
2	S-B	36.1	1.25	39	2.40	76
3	S-AH	55.5	0.45	33	2.22	60
4	S-M	52.9	0.16	42	2.60	67
5	S-PM-B	26.2	1.79	35	2.39	82
6	S-AH-B	30.5	4.00	32	2.05	76
7	S-M-B	38.0	0.90	42	2.45	75
8	S-M-AH	41.8	2.70	41	2.20	70
9	S-PM-AH	37.4	0.91	43	2.28	74
10	B-PM-AH	14.3	3.73	37	1.60	86
Difference required for significance		1.9	0.90	3	—	—
11	S-Sa(?)	71.7	0.11	45	—	57
12	S(clay loam)	59.2	0.10	46	—	64
13	S-Sa(10%)	63.6	0.06	44	—	62
14	S-Sa(30%)	70.4	0.08	41	—	57
15	S-Sa(50%)	84.2	0.10	36	—	49
16	S-Sa(70%)	92.3	0.05	33	—	44
17	S-Sa(90%)	92.9	0.18	33	—	44
18	Sand	92.3	0.26	29	—	44
Difference required for significance		2.4	0.03	2	—	—

[z] S=soil; PM-peat moss; B=bark; AH=almond hulls; M=manure; Sa=sand. Equal proportions except where percentages of sand indicated. Note that mixtures 1 through 9 used S-Sa(?), No. 11 for basic soil.

[y] Steady state rate with ½-inch water head on surface of 8-inch deep column of mixture.

[w] Moisture content by volume for 8-inch deep column after drainage ceased.

[v] Ratio of weight of soil to water, no dimensions.

[u] Calculated from given specific gravity, 2.65 assumed for mixtures 11 through 18.

Table 3: Percolation rates and maximum moisture holding contents of 8-inch deep, freely draining, soil cores, with ½-inch water head continuously maintained on the soil surface.

Description	Percolation rate (gal per min per sq.ft.)	Moisture content[z] (%)
1. Clay loam field soil	0.10	46
2. Pure sand	0.26	29
3. Clay loam with sand, ranging from 10 to 90% of final volume	0.10	39
4. Clay loam with sand (ca 15%) mixed with various amendments at a 1:1 ratio, final volume	0.54	40
5. Clay loam with sand (ca 15%) mixed with various amendments at a 1:1:1 ratio final volume	2.06	39
6. 1:1:1 ratio final volume of pine bark, peat moss and almond hulls	3.73	37
Difference required for significance (the probability that this value is wrong is 1 in 20)	1.15	7

[z] Maximum moisture content by volume after drainage ceased.

Discussion

We have known for some time at least one disadvantage with greenhouse soils that have been extensively modified. The capillarity of the mixture is decreased, often to a point where small seedlings may be very difficult to establish without excessive watering. It appears we can add another disadvantage. That is, attempting to control salinity by straight-forward flooding of the mixture is very inefficient water utilization. In fact, percolation rates were so high with some of these mixtures, that it was unlikely that any irrigation system now in greenhouse use could have actually flooded the surface by delivering sufficient water. This work has pointed out that we know relatively little about efficient methods for leaching or controlling salinity in most greenhouse mixtures. Why is leaching efficiency not a function of water volume? Should leaching be carried out over several water applications? How much water do we waste when we recommend that some leaching occur at each watering? Would it be better to wet and leach several times, rather than to attempt leaching in one application? There are numerous theories and studies on leaching of soil under field conditions, but very few for extensively modified soil mixtures. We can suggest at this time, that soils with high percolation rates will require at least double their maximum moisture holding capacity (2 to 4 gallons per sq. ft.) to remove 50% of the salts in excess of the applied water. And, this amount increases rapidly the lower the initial salt concentration. We are saying, in effect, that it is easier to remove 50% if you start at 10,000 μmhos/cm than if you start at 5000 μmhos/cm. If the percolation rate is less than about 0.5 gal per min per sq. ft., leaching efficiency increases to where 50% of the excess salt can be removed with less than 1 to 2 gallons of water per sq. ft. These

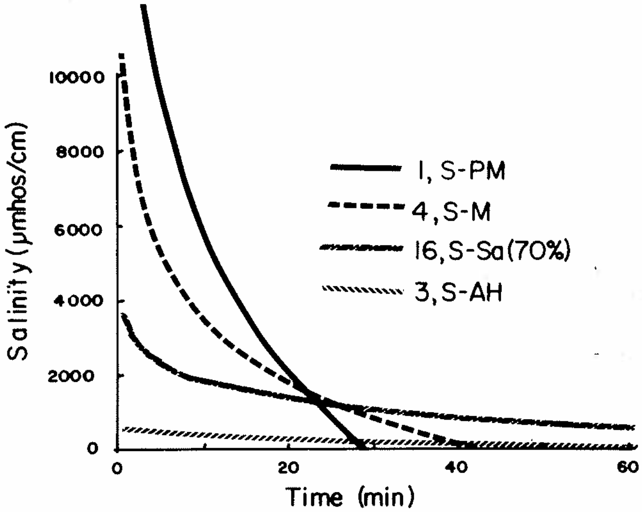

Fig. 2: Calculated leaching curves for 4 representative root media. These curves are straight lines when time is transformed to logarithms. Correlations of 0.90 or higher in each case, and they are statistically significantly different from zero and from each other.

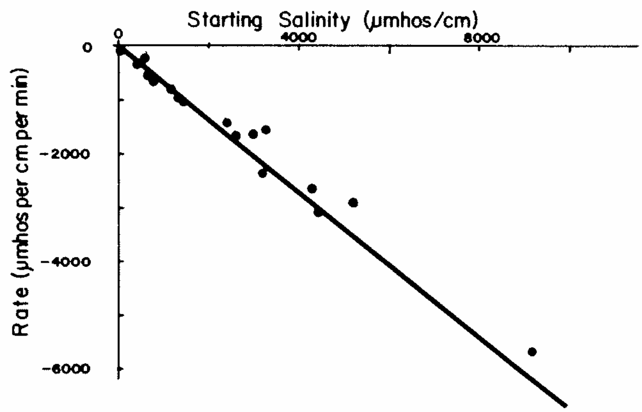

Fig. 3: The rate of leaching salts from 8-inch deep columns of 16 root media when plotted as a function of the starting salinity and the soil surface is flooded. All mixtures are combined, with a correlation coefficient of 0.99 for the calculated straight line. For these mixtures examined in this study, the time required to leach one of them can be predicted by knowing the starting concentration of the salts.

Table 4: Water quantity and time required for leaching 8-inch deep soil columns when maintaining ½-inch water head on the upper surface.

Soil Number	Description[z]	Salinity: Starting (μmhos/cm)	Salinity: rate[y]	To remove 50%: Time (min)	To remove 50%: Water (gal/ft²)	To remove 75%: Time (min)	To remove 75%: Water (gal/ft²)	To remove 100%: Time (min)	To remove 100%: Water (gal/ft²)	Moisture content[x] (gal)
1	S-PM	17993	-12306	5	1.5	13	3.8	29	8.4	2.2
2	S-B	1336	-992	5	6.3	10	12.5	22	27.5	1.9
3	S-AH	562	-275	11	5.0	34	15.3	110	49.5	1.6
4	S-M	9217	-5709	6	1.0	16	2.6	41	6.6	2.1
5	S-PM-B	652	-569	4	7.2	7	12.5	14	25.1	1.7
6	S-AH-B	3218	-2370	5	20.0	10	40.0	23	92.0	1.6
7	S-M-B	1194	-816	5	4.5	13	11.7	29	26.1	2.1
8	S-M-AH	450	-378	4	10.8	8	21.6	16	43.2	1.8
9	S-PM-AH	821	-683	4	3.6	8	7.3	16	14.6	2.1
10	B-PM-AH	70	-53	5	18.7	10	37.3	21	78.3	1.8
11	S-Sa(?)	3068	-1663	8	0.9	24	2.6	70	7.7	2.2
12	S(Clay loam)	5278	-2928	8	0.8	22	2.2	64	6.4	2.3
13	S-Sa(10%)	2517	-1447	7	0.4	20	1.2	55	3.3	2.2
14	S-Sa(30%)	2707	-1691	6	0.5	16	1.3	40	3.2	2.0
15	S-Sa(50%)	4399	-2660	7	0.7	11	1.1	45	4.5	1.8
16	S-Sa(70%)	3382	-1571	17	0.6	41	2.1	142	7.1	1.6
17	S-Sa(90%)	4568	-3102	5	0.9	13	2.3	30	5.4	1.6
18	Sand	1590	-1058	6	1.6	13	3.4	32	8.3	1.4

[z] S=soil, PM=peat moss, B=bark, M=manure, Sa=sand. Mixtures 1 through 9 used No.11 (S-Sa(?)) as the basic additive to the equal volumes of other additives.

[y] The rate is μmhos per cm per min, values calculated by fitting the experimental points to a curve with time transformed to logarithms. Note that the rate is not constant in this type of transformation.

[x] Calculated moisture content of a square foot of mixture, 8-inches deep.

relationships may be due to the fact that the major water flow in porous media occurs through the large pores, and very little salt is dissolved in the process. In tight soils, the water moves through the soil in a "front", pushing the salts out ahead of it.

Until such time that we have more information, recommendations continue to suggest that some leaching be allowed at each watering. Salt levels higher than absolutely necessary for nutrition will invariably reduce yield and growth rates of most commercial greenhouse crops. It is probable that, when actually necessary to bring down salt levels in highly porous mixtures, one should make several applications, leaching slightly each time and allowing some time between leachings for salts to enter solution. The "leaching requirement" as calculated for field soils does not seem, at this point, as good a method to apply to greenhouse mixtures for salinity control. The point should be made that the lower the salt concentration of the applied water, the faster leaching will occur. Where automatic fertilization is employed, it seems reasonable to conclude that water requirements for salinity control will be increased markedly if the grower desires to maintain minimum salinity. It would be a good practice to monitor salt levels of applied water at regular intervals, increasing the amount of water applied at any one irrigation the higher the salt concentration. With very porous mixtues, it is probably impractical to attempt leaching, using a trickle irrigation system.