Optimizing Container Soil Amendment: The “Threshold Proportion” and Prediction of Porosity1

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Abstract. The quantity of amendment required to ensure adequate aeration in container soils is usually determined by empirical tests on a series of mixtures containing different amounts of the amendment. In this study, the “threshold proportion” or minimum amount of amendment required before aeration improvement begins, was demonstrated to be controlled by amendment interporosity. This concept is the basis for a method of predicting total and aeration porosity of any container soil mixture.

Soil in a container (e.g. pot, can, flat, bench, planter) is distinguished from the same soil in a ground bed by its smallness and shallowness. Smallness causes inadequate total water and mineral storage and shallowness causes excess soil water content and poor aeration because of a perched water table formed at the container bottom after irrigation and drainage (6, 14, 15). An irrigated and drained, fine or medium-textured natural soil in a container will likely be saturated throughout. The deleterious effects of smallness are usually remedied by frequent irrigation and fertilization; however, this increases the occurrence of poor aeration. This dilemma is removed by incorporating coarse-textured amendments (e.g. sand, gravel, perlite, calcined clay, vermiculite, sawdust, bark, nut shells, peat, etc.) into the soil to increase the amount of large or aeration pores (2) which drain despite the water table (1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16). Too much amendment decreases water storage excessively and too little reduces both water storage and aeration. The optimum amount of amendment creates soil physical conditions which closely match plant requirements. The optimum is usually selected by the “trial-and-error” method of growing plants in a series of mixtures. Elimination of this inefficient and inaccurate procedure would be a significant advance in the development of soil mixtures. This preliminary paper demonstrates the concept of “threshold proportion” as the basis for predicting and controlling the total and aeration porosity of any amendment-soil mixture and as an index for optimizing container soil amendment.

Symbols used are summarized in Table 1. Mixture porosity as a function of soil and amendment bulk volumes3 is shown in Fig. 1 and generalized in Fig. 2. Since mixtures are usually prepared from bulk quantities (e.g. ft3, bu, yd3, liters, m3, etc.), component and mixture quantities are herein expressed as bulk volumes. Beginning with 100% soil (Em = Eo), increasing the amendment proportion4 first decreases Em to a minimum, the threshold proportion (TP), then increases it until the mixture is 100% amendment (Em = Eb). Since soil can occupy amendment pores, soil bulk displaced by the addition of amendment equals amendment solid, not bulk, volume. Therefore, aVb increased more rapidly than sVb decreased (aVb + sVb > mVb unless aVb or sVb = 0). Less amendment than the TP “floats” in the soil, displacing soil volume and Es without adding Ea. At the TP, the container is exactly full of amendment (aVb = mVb = 100 cm3) and the amendment’s pores are exactly filled with soil (sVb = Eb × 100 cm3) and Em and aeration porosity are minimal. In this example, only about 35% of original soil volume, potential water storage, and potential aeration remain at the TP, the other 65% is excluded by amendment solids. As sVb is reduced from the TP, Em is voided of soil and total and aeration porosity increase. These effects depend on amendment particles being many degrees of magnitude larger than soil particles and are most predictable in compacted mixtures containing monodisperse5 amendments.

Mixture total and aeration porosities can be predicted from component bulk volumes and porosities:

\[ E_m = [mV_b - aV_b(1 - E_a)]E_a + aV_bE_a^s \] (A)

when aVb is less than that at the TP and

\[ E_m = mV_b - (sV_b(1 - E_a)) + aV_b(1 - E_a) + aV_bE_a^s \] (B)

when aVb is greater than that at the TP.

Em is then estimated from:

\[ E_A = E_m - (sV_bE_a + aV_bE_a^s) \] (C)

Simple graphical prediction of Em and EA is demonstrated in Fig. 2. To prepare a mixture with 25% total porosity, 100 cm3 of this amendment should be mixed with about 20 cm3 of soil; about half of the resulting porosity is aeration porosity.

The actual aeration increase realized from EA in a given situation depends on E, magnitude, pore size and continuity, and container depth and is the subject of continued study. The TP is actually the least desirable container soil mixture, however, it delimits the minimum or “threshold” amount of amendment required to effect container soil improvement and provides a basis for the prediction and quantification of mixture physical properties as a first step towards optimizing container soil mixtures. Factors which reduce E (e.g. particle compaction, shape, and size distribution) increase the TP (3, 4, 5, 8, 10, 11, 12, 13). Polydisperse5 materials

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3Bulk volume = Vp + Vs (expressed as fraction of mVb in calculations).
4Amendment proportion = sVb / (sVb + aVb); soil proportion = sVb / (sVb + aVb).
5Monodisperse = narrow range of particle sizes; polydisperse = wide range of particle sizes.
The method for predicting and controlling soil mixture physical properties described herein should prove to be a significant and useful tool in the development and optimization of container soil mixtures.

**Literature Cited**