CONTAINER SOIL WATER RELATIONS: PRODUCTION, MAINTENANCE, AND TRANSPLANTING[1]

by L. Art Spomer

Container soils are different. Almost everyone has grown plants in containers.. What is a container? It is any receptacle filled with soil or other growth media in which plants are grown. The commonly used containers include pots, flats, planters, cans, boxes, cartons, greenhouse benches, baskets, and tubs.

Most horticultural crops including those grown in nurseries (with the exception of field crops) are propagated from seeds or cuttings and are grown in containers until they are large enough to transplant into ground beds in gardens or yards. Most floricultural crops, house plants and an increasing number of bedding plants and woody plants (in urban areas) are grown exclusively in containers. Container culture, therefore, is a very important aspect of horticulture and arboriculture. So anyone concerned with horticultural crop production and sales must know something about container soils. Although containers are widely used in horticulture and arboriculture, few people in these fields realize that container soils are different. The purpose of this paper is to review the special characteristics of container soils with particular reference to their use for producing plants for transplanting into ground beds.

The soil's most important function relative to plants is to store and supply the water and minerals essential for plant growth and survival. It is not enough for the soil to merely CONTAIN water and minerals; they must be AVAILABLE to the plant. A number of soil and plant factors affect the availability of water and minerals in the soil to plants. One of the most important is soil aeration. This is the supply of oxygen to and the removal of carbon dioxide from the plant roots. Good aeration is essential for adequate root growth and absorption, by which the plant grows and survives.

All soils physically consist of a semirigid mass of minute solid particles permeated by a network of interconnected pores in which water, mineral nutrients, and air move and are retained. A container soil is isolated from the ground by the container and is usually open to the atmosphere at the top (surface) and bottom (drainage holes). The depth of a container soil is the vertical distance between the surface and drainage level.

Container soils have two important characteristics that distinguish them from ground bed soils: container soils are small and shallow (Figure 1). The effect of the relatively small volume of soil in a container is obvious. The reservoir of available soil, water and minerals is much smaller for container plants than for those growing in ground beds; therefore, this reservoir must be replenished by frequent irrigation and fertilization to maintain equivalent growth by the plants in containers.

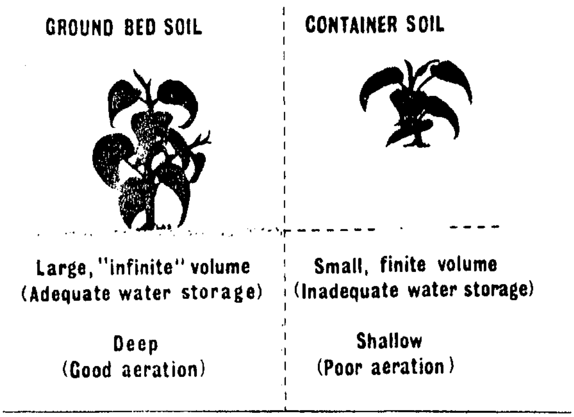

Figure 1. Container soils are smaller and shallower than ground bed soils. Both of these characteristics tend to reduce potential plant growth in containers.

The effect of shallowness in relation to container soils is less obvious. It can be demonstrated easily, however, with an ordinary flat cellulose sponge, like the one you use to scrub the bathroom or car. Place the sponge flat on the level, spread the fingers of one hand, and saturate

[1]Presented at the annual meeting, Midwestern Chapter, ISA, in Champaign, Illinois in February 1980.

the sponge by pouring water on it until water drips from the bottom. The sponge, like the soil, is permeated by pores that are full of water when the sponge is saturated. In other words, the sponge is a good model, or analog, of a container of soil. The sponge behaves like soil. After water ceases to drip from the flat sponge, placing it on end will permit more water to drain out (its water content decreases). Merely increasing the height of the sponge by turning it up on end decreases its water content.

Container soil behaves the same way. Actually, a perched water table forms at the bottom of the container soil (the drainage level), even though it has free drainage (open at bottom). Like any water table, the soil is saturated (the pores are filled with water); also, the water content decreases with the height above the water table.

Because of this "container soil effect," an excellent garden or field soil placed in a container will probably remain saturated following watering and drainage and result in poor soil aeration and poor plant growth. Even if the container is filled with coarse sand or perlite, the soil may remain saturated following irrigation and may be poorly aerated because of its shallowness (Figure 2). The deeper the container soil, the smaller its surface and average water content following watering and drainage.

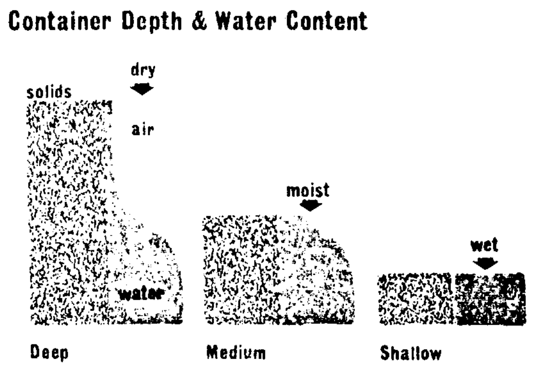

Figure 2. The water and air content as a function of height for the same soil placed in containers of three different heights. The deepest container is likely to be "too dry" and the shallowest container "too wet" following watering and drainage.

The effects of the container's smallness and shallowness create a dilemma. The soil in a container holds an inadequate supply of water and minerals to maintain growth for more than a short period; yet, that same soil may be too wet for the plant to absorb even this inadequate supply (Figure 3). The effects of the container's small size can be remedied by frequent watering and fertilization; however, that also increases the frequency of poor aeration (due to the shallowness of container soil).

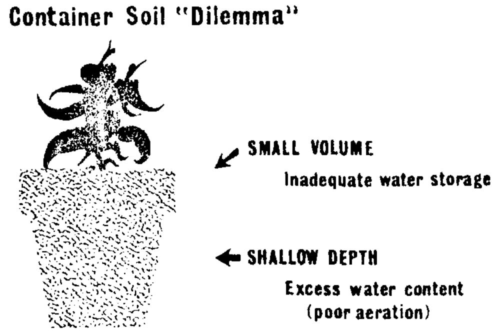

Figure 3. The container soil 'dilemma' is reduced in *practice through a combination of frequent irrigation* (and fertilization) and soil amendment (soil mixes).

The effects of shallowness can be remedied by incorporating coarse-textured amendments (sand, sawdust, peat, perlite, bark, vermiculite, calcined clay, and the like) into the soil creating large pores that will drain after watering, despite the perched water table at the container bottom. However, insufficient amendment worsens aeration instead of improving it; and excess amendment results in insufficient water retention for growth. Although the relatively small size and shallowness of containers do create problems for growing plants, the problems can be minimized by proper irrigation and fertilization and by using soil amendments.

Remember that **container soils are different.** Therefore, they require different care than garden or field soils.

Container soil amendment. A container soil has two important characteristics that distinguish it from the same soil in a ground bed. The container soil is relatively small in volume and shallow in depth (Figure 4). The effects of the small volume on plant growth are rather obvious. The container soil does not store enough water and minerals to support growth for more than a short time.

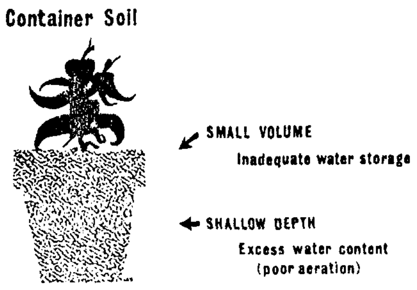

Figure 4. The two most important characteristics of any container soil are its small volume and shallow depth.

The effects of shallowness, excessive water content, and poor aeration may be less evident. Following thorough irrigation and drainage, a perched water table forms at the bottom (drainage level) and the soil is saturated there, but the water content decreases with height above the bottom. So a container soil contains too little water to maintain plant growth while, at the same time, being too wet for the plant to absorb even the insufficient moisture available. This dilemma of a "too dry" and "too wet" soil is solved in practice through the use of soil amendments, or soil-less media. This section briefly discusses how the physical properties of soil change when we add amendments to it.

The distribution of water in a container soil depends on the depth of the soil and the kind of soil (actually, the size distribution of its pores). Figure 5 shows the water distribution patterns for a very coarse-textured sand (A), a silty clay loam (C), and a mixture of sand and loam (B) in a 10-inch (25-cm) deep container (following irrigation and drainage).

The sand has excellent aeration but poor water retention, whereas the loam is essentially saturated throughout its entire depth. A plant growing in the sand is likely to suffer from periodic drought. A plant growing in the loam will suffer from periodically poor aeration. The main physical difference between the sand and the loam is that the sand contains predominately large aeration pores, which drain despite the perched water table, whereas the soil contains predominately small water-retention pores which remain full of water under the influence of the water table.

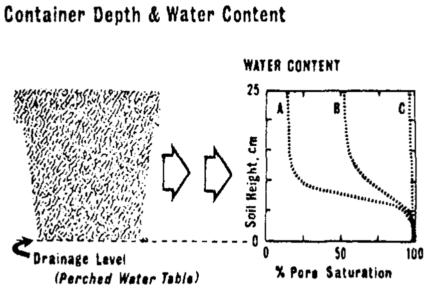

Figure 5. A perched water table forms at the container bottom following irrigation and drainage, and water content decreases with height above the bottom. Line A indicates the water distribution pattern for a very coarse-textured sand; C, a silty clay loam soil; and B a mixture of A and C.

An ideal container soil would be a compromise between these two extremes and is achieved in practice by mixing enough coarse-textured amendment material (such as sand, perlite, calcined clay, vermiculite, peat, sawdust) with soil to form enough aeration pores to insure adequate aeration.

Unfortunately, if too little of the amendment material is used, both aeration and water retention are decreased; if too much is used, water retention is decreased. Figure 6 depicts a microscopic view of a soil. Figure 7 illustrates what happens to soil porosity when an amendment (sand in this case) is mixed with soil in increasing proportions. Insufficient amendment (B, C, D) merely excludes soil volume without adding any aeration pores, so total porosity decreases. At the "threshold proportion" (D), the mixing bin is exactly full of amendment and the aeration pores between the amendment particles are exactly full of soil; consequently, total porosity is at a minimum. So, this is the worst possible soil mixture in which to grow plants.

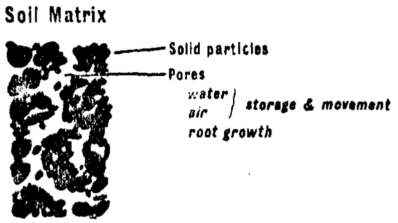

Figure 6. A microscopic view of a soil, illustrating the relationship between the particles and pores.

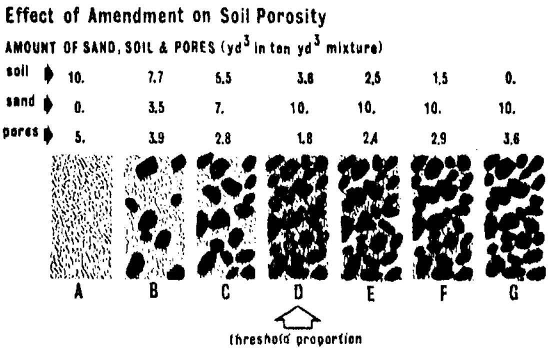

Figure 7. The effect of mixing increasing proportions of an amendment (very coarse-textured river sand) with soil (silty clay loam) on porosity. Total volume of the mixing bin was 10 cubic yards and the volume of pores are listed above a microscopic diagram of each mix. Mix A is 100% soil and mix G is 100% sand. Note that the component volumes in B, C, D, E, & F do not add up to equal 10 cubic yards.

As the amendment proportion is increased above the threshold (E, F, G), aeration pores are voided and aeration and total porosity are both increased. Looking at this in another way, at and below the threshold (A, B, C, D), amendment particles merely occupy space in the container without adding any porosity. At the threshold and above (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 8.

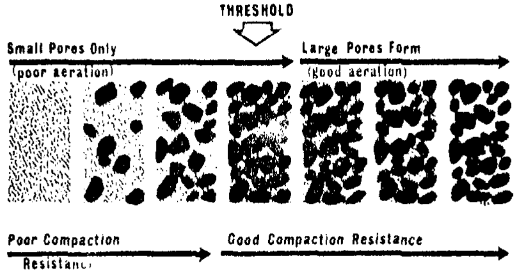

Figure 8. Effect of soil amendment on soil pores and aeration. Small pores are water retention pores in container soils.

This same principle holds true in soil-less container media where one component's particle size is several times larger than that of another (for example, bark and fine-sand mixtures).

The "threshold proportion" is the *minimum* amount of amendment that must be added before any improvement in aeration can be expected. The threshold proportion depends on the shape of the amendment particles and, to a lesser extent, on their size and is a direct function of the aeration porosity of the amendment alone. The threshold proportion for sand, perlite, calcined clay, and similar amendments is approximately 10 volumes of amendment plus about 2½ or 3 volumes of soil. Organic amendments such as peat, bark, and others generally require less amendment material to reach the threshold proportion.

This section has discussed briefly what happens to the physical properties of soils when they are amended for use in containers. The specific mixture depends on the container size and depth, the plant, the climate, the method and frequency of irrigation, and other factors.

Water Retention of Transplanted Container Soils. Growing plants in the greenhouse or nursery until they are mature enough to transplant usually gives them a good start over those seeded directly in the field. Perennial transplants, such as fruits and landscape shrubs or trees, typically have a growth advantage of 1 to 10 years or more depending, of course, on the age and size of the transplant. Annual transplants or bedding plants have an advantage of 3 to 10 weeks or perhaps longer. This section briefly discusses the water retention of container soils transplanted into ground beds and the probable effect on plant growth and survival.

Many horticultural and arboricultural crops are transplanted at some stage in their life cycle. We often hear the term "transplanting shock" used to describe the delay in growth that usually results from transplanting. This transplanting shock usually results from direct injury to roots. To avoid such injury, many plants are transplanted without being removed from the soil mass in which they are growing. In fact, various kinds of special containers have been developed to facilitate transplanting with a minimal disturbance of the roots. Unless special precautions are observed, however, the practice may result in another type of transplanting shock, water stress. Plants develop a water stress whenever they lose more water by evaporation than they absorb from the soil.

Water loss is controlled by a number of different plant and meteorological factors, which are usually beyond practical control in the field. Water absorption depends largely on the amount of available soil water. That, in turn, is determined by the soil type, drainage depth, precipitation or irrigation frequency, and extent of the root system.

A mild or moderate water stress usually slows or stops growth. Severe or prolonged stress may injure or kill plants, either by impairing such vital functions as photosynthesis and respiration or by predisposing them to infection by disease-causing organisms that normally attack only weakened plants.

Transplants often suffer from greater water stress than plants seeded directly. In bareroot transplants, the roots may be dried, injured, or lost during transplanting, thus reducing the plant's capacity to absorb water. Container-grown transplants usually suffer little if any direct root injury but may still manifest water stress after transplanting. The cause would be inadequate water retention by the transplanted container soil.

As described previously, special soil mixes are required for containers. A perched water table forms at the bottom (drainage level) of these containers following irrigation and drainage. A coarse or very coarse-textured growth medium containing enough large air spaces or "aeration pores" is essential in such containers to allow adequate aeration for root growth and absorption and to prevent disease infestation.

When a special container growth mix designed for shallow containers is transplanted into the ground beds, which have very much deeper drainage depths, the soil dries out because of drainage into the underlying soil (Figure 9). In other words, the transplant soil almost always dries out faster than the same soil would if it were still in the container (under otherwise identical conditions).

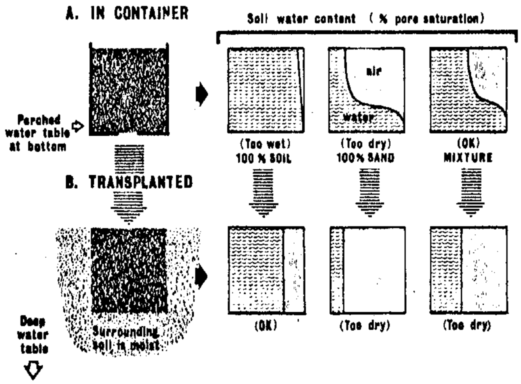

Figure 9. The effect of transplanting on the water content of 3 different soils: 100 percent field soil, 100 percent coarse sand, and a mixture of soil and sand. A shows the water content of these soils still in a container, while B shows the water content of the same soils transplanted into a ground bed (deep drainage). The container is about 5 inches deep.

In a contained soil, the container confines the roots to a limited soil volume and water supply. This supply typically amounts to just enough water to sustain the plant for 2 days or less, especially when the potential for evapotranspiration is high. Thus, frequent irrigations may be required to maintain an adequate supply of water for plants in containers. When a container soil is transplanted into a ground bed, the soil type and volume remain the same until the plant's roots grow out into the field soil. However, the water draining from the transplanted soil usually increases several fold, so that it retains less water after irrigation or precipitation than it would if it were still in a container (Figure 10).

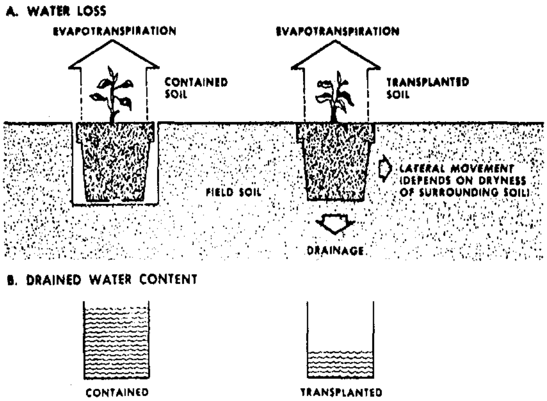

Figure 10. (A) A contained soil loses water by evaporation or evapotranspiration only, but a transplanted container soil also loses water to the surrounding soil, primarily as a result of drainage. (B) A perched water table forms in the contained soil but not in the transplanted soil. A coarse-textured container soil mixture may retain more than twice as much water when contained as when transplanted.

Compounding the effects of this reduced water retention is the decrease in irrigation frequency or the complete lack of irrigation in many field locations. The net effects of increased drainage depth and decreased irrigation frequency are greater water stress and a reduced growth and survival of the transplants. This drying effect on the transplanted soil continues to affect the plant until its roots grow out into the surrounding soil. However, the accelerated soil drying delays this root growth, thus compounding the transplanting shock.

In other words, the transplant will surely suffer from lack of water, a water stress, unless special precautions are taken.

To avoid such stress, provide: 1) more frequent irrigation; 2) shading or other protection for the plant from excessive drying; and 3) a soil mix that contains sufficient small, water-retention pores to reduce the drainage of water out of the transplanted soil ball. The first two precautions should be exercised until the roots have grown out of the transplanted soil mass and have become established in the surrounding soil. The actual irrigation frequency depends on several factors, but it should always be greater for the transplant than for that same plant in a container. The last precaution, the use of a special soil mix, requires a compromise between a medium that is best for a container and one that is best for transplanting into a ground bed. In addition to the preceding precautions, everything possible should be done to promote root growth into the surrounding soil.

In summary, transplanted soils retain less water than the same soils in containers. So special care must be taken to minimize or to avoid the adverse effects of this phenomenon.

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