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Calculation of Growing Medium Bulk Volume Using Medium Height and Pot Dimensions

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One of the most important aspects of the physics of growing media in containers is the limited bulk volume of the medium (2,4). Bulk volume (BV) includes the volume of the medium solids and pore spaces (1). Despite the importance of BV in determining the amounts of air, water, and nutrients in the pot, BV is rarely specified in research articles involving plant growth in container media. Without BV, volumetric properties, such as bulk density (g/ml), container capacity (percent by volume), air-filled porosity (percent by volume) and fertilization and liming rates (kg/m^3), cannot be converted to absolute amounts per pot. The purpose of this study was to develop equations to calculate BV using pot dimensions and medium height in the pot.

A typical plant pot (Fig. 1) is a tapered cylinder. Geometrically, a tapered cylinder is termed a frustrum of a cone (3), so a pot consists of two frustrums (or frustra) of a cone, one on top of the other. The volume (V) of a frustrum of a cone is calculated (3) using the top and bottom radii (r_t, r_b) and the height (h), $V = \pi\, h/3\, (r_t^2 + r_t r_b + r_b^2)$.

To calculate pot volume, four radii and two heights (Fig. 1) are utilized. These dimensions can be measured easily by using a ruler and a pair of inside calipers. Pots usually are not filled completely with medium to provide a freeboard space to add water. Therefore, to calculate BV, either the height of medium (h_m) in the pot or the radius at the medium surface (r_m) must be known. Since h_m and r_m vary depending on the packing procedure, equations should be sufficiently flexible to calculate BV for any h_m or r_m. Because of pot geometry, two pairs of equations are needed. If $h_m > h_3$, where $h_3 = h_1 - h_2$ (Fig. 1) or $r_m > r_3$, then BV is calculated using equations 1 or 2, and 3 (Table 1). Otherwise, equations 4 or 5, and 6 are used.

A BASICA program was written on an IBM-PC compatible computer to calculate BV as a function of h_m using the equations in Table 1. A 15-cm standard plastic pot with dimensions (cm) of $r_1 = 7.50$, $r_2 = 7.05$, $r_3 = 6.60$, $r_4 = 5.30$, $h_1 = 14.5$, and $h_2 = 3.8$ was used as an example. A graph of h_m vs. BV (Fig. 2) can function as a standard curve allowing calculation of BV if h_m is known. The increase in BV with increased h_m is shown for the 15-cm pot (curve B) and a cylinder (curve A) (Fig. 2). Because of pot taper, the BV per unit height increases with h_m in the pot but remains constant in the cylinder. With the pot filled with medium, the top 1-cm layer of medium has BV = 174 ml, whereas the bottom 1-cm layer has BV = 90 ml. This increase in BV with increased h_m partially offsets the decrease in volumetric moisture content as h_m increases (4). The equations (Table 1) can calculate BV of container media for research and can estimate number of pots filled per m^3 of medium.

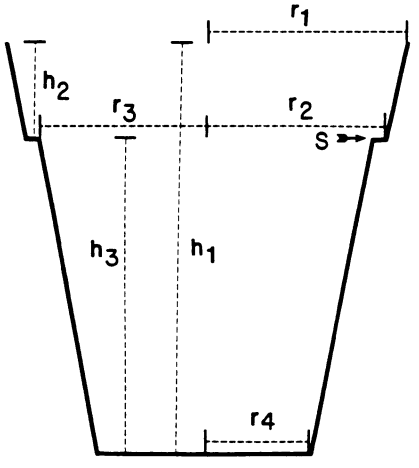

Fig. 1. Cross-section of typical plant pot showing dimensions needed to calculate pot volume. S indicates pot shoulder. r_1 = top inside pot radius, r_2 = larger inside radius at pot shoulder, r_3 = smaller inside radius at pot shoulder, r_4 = bottom inside pot radius, h_1 = inside pot height from base to top, h_2 = inside pot height from shoulder to top, and $h_3 = h_1 - h_2$.

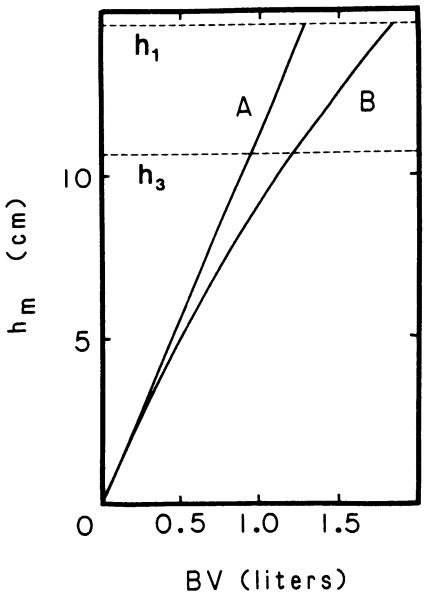

Fig. 2. Standard curve to determine medium bulk volume (BV) from the height of medium (h_m) in a cylinder (A) and a 15-cm plastic pot (B). Cylinder radius is 5.3 cm. Pot dimensions (cm) are top inside radius, $r_1 = 7.5$; larger inside radius at shoulder, $r_2 = 7.05$; smaller inside radius at shoulder, $r_3 = 6.6$; bottom inside radius, $r_4 = 5.3$; inside height from base to top, $h_1 = 14.5$; inside height from shoulder to top, $h_2 = 3.8$ and inside height from base to shoulder, $h_3 = 10.7$. Dashed lines indicate h_1 and h_3.

Table 1. Equations to calculate bulk volume (BV) of growing media in pots.[z]

If $h_m > h_3$ or $r_m > r_3$, use equations (1) or (2) and (3).

(1) $r_m = r_2 + (h_m - h_3)(r_1 - r_2)/h_2$

(2) $h_m = h_3 + h_2(r_m - r_2)/(r_1 - r_2)$

(3) $BV = \frac{\pi}{3}\,[h_3(r_3^2 + r_3 r_4 + r_4^2) + (h_m - h_3)(r_2^2 + r_2 r_m + r_m^2)]$

If $h_m \leq h_3$ or $r_m \leq r_3$, use equations (4) or (5) and (6).

(4) $r_m = r_4 + h_m(r_3 - r_4)/h_3$

(5) $h_m = h_3(r_m - r_4)/(r_3 - r_4)$

(6) $BV = \frac{\pi}{3}\,[h_m(r_m^2 + r_m r_4 + r_4^2)]$

[z] h_m = medium height in pot, r_m = radius at medium surface, r_1 = top inside pot radius, r_2 = larger inside radius at pot shoulder, r_3 = smaller inside radius at pot shoulder, r_4 = bottom inside pot radius, h_2 = inside pot height from shoulder to top, h_3 = inside pot height from base to shoulder.

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