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Prediction of Bulk Density of Pine Bark and/or Sand Potting Media from Laboratory Analyses of Individual Components

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Additional index words. shrinkage, predictive equation

Abstract. **An equation for predicting bulk density (BD) of pine bark and sand potting media was devised using BD data from laboratory analysis of individual components. BD values calculated from the predictive equation and actual values obtained from potting medium samples were compared. Actual and predicted BD increased linearly with each incremental increase in percentage sand in the medium. Actual and predicted BD values were not significantly different. The devised equation is applicable to media other than bark and sand.**

Container potting media have been developed which attempt to satisfy the requirement of reproducibility. Reproducible results are desirable in order that standardized cultural practices may be used to obtain consistent plant performance (8). Rising costs and questioned availability of certain widely used medium components have led researchers to seek other readily available low cost alternatives. Selection and blending of medium components often is done empirically, and testing of the product is time consuming and costly.

Mathematical equations and models have been developed for simulation and predicting plant growth (1), insect populations (6), vegetative maturity (15), rest prediction (4), root growth (17), and economic models of various types (3, 16). As pointed out by Sahin et al. (18), models are needed when it is physically or economically impractical to conduct actual experiments or when a project is still in preliminary stages.

Selection of medium components and blending ratios, to achieve desirable potting medium properties at reduced cost, might be achieved by physical and chemical analysis of individual components in the laboratory and simulating properties of any given blend. Simulated blends exhibiting suitable properties then would be selected for further evaluation. Development of the necessary predictive equations could lead to computer modeling of container media (11).

The objectives of this research were: 1) to devise, and 2) test a mathematical equation for predicting bulk density (BD) of a 2 component (pine bark-sand) potting medium.

Materials and Methods

Predictive equation. During equation formulation, it was assumed that each potting medium component would contribute weight in proportion to its volume percentage in the potting blend. Thus, an equation initially was stated as $D_m = \frac{(V_tC_1)(D_1) + (V_tC_2)(D_2)}{V_t}$ [1] where: D_m = predicted BD (gm/cm^3) of volume mixture; V_t = total sample volume; C_1 = volume percentage component 1; C_2 = volume percentage component 2; D_1 = BD (gm/cm^3) component 1; and D_2 = BD (gm/cm^3) component 2.

Applying equation 1 to Pokorny and Henny's data (13) under-

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estimated weight per unit volume when compared to actual BD. This underestimation occurred because shrinkage was not accounted for in the equation. Shrinkage or reduction in bulk volume occurs when 2 or more loose components, differing in particle-size distribution are mixed and the final volume of the mixture is less than the sum of the volumes of the individual components (19). Therefore, equation 1 was restated as

$$D_m = \frac{(V_tC_1)(D_1) + (V_tC_2)(D_2)}{V_t - S}$$

[2] where terms are defined above; and S = percent shrinkage.

Shrinkage curve. A shrinkage curve was developed using milled pine bark and sand as medium components and blending the components in volume ratios (bark to sand) of 0%, 10%, . . . 90%, and 100% (Table 1).

Air-dried milled pine bark (30°C – 3 weeks) and air-dried sand were sieved using U.S. Standard sieves with openings of 4.76, 2.38, 2.00, 1.00, 0.84, 0.60, and 0.42 mm (mesh numbers 4, 8, 10, 18, 20, 30, and 40). Particles passing through the screen with 0.42 mm openings were retained in the receiver pan (13). Particle size fractions for each medium component were stored separately.

Each of 11 potting media (Table 1) were constructed from bark and sand particles. Components were mixed thoroughly in a rotary drum and samples transferred to 100 ml polypropylene graduated cylinders. Cylinders were clamped to the arms of a Burrell wrist-action shaker with the base of the cylinders placed in a wooden box. Shaking time was 20 min with bases of the cylinders striking each side of the box (12). Volume was obtained by direct reading of the graduated cylinder; percentage of shrinkage was calculated from a theoretical 100 cc volume and actual sample volume after compaction.

The experiment, with 11 media each replicated 10 times, was conducted in a randomized complete block design. Regression analysis was used to delineate the shrinkage curve (10).

Testing predictive equation. Potting medium samples were synthesized as previously described (Table 1). They were oven-dried (105°C–24 hr), weighed, placed in graduated cylinders, and mechanically compacted for 20 min (12). Volume of each sample was recorded. Actual BD was determined and a predicted BD was calculated using equation 2. Each replicate BD value for bark and sand was paired for calculational purposes.

The experiment was conducted in a randomized complete block design with 11 media, each replicated 10 times. Regression analysis was used to delineate medium influence on BD; homogeneity of variances was determined, and a test of equality of regression equations performed (10).

Application of predictive equation. Literature evaluating physical properties of 2 component container media was searched for reported BD data. Three items of BD information, namely, a) BD of component 1, b) BD of component 2, and c) BD of the component 1 and component 2 mixture were required to evaluate the predictive equation with medium components other than pine bark and sand. Shrinkage (loss of volume on mixing) for each potting mixture (Table 2) was estimated by calculation using equation 1, dividing by actual BD, and subtracting the result from 100. Predicted BD was calculated using equation 2.

Results and Discussion

Loss in volume (shrinkage) associated with mixing bark and sand in different volume ratios is given (Fig. 1). The shrinkage curve is curvilinear and approximates an inverted V. Each arm of the shrinkage curve is curvilinear — the left side a mirror image of the right side. Thus, only 3 values (100%–sand, 75% sand–25% bark, and 50% sand–50% bark) are required to establish the form of the shrinkage curve using bark and sand as potting medium components. The percentage of shrinkage may be larger or smaller than values obtained in this work, depending on the texture of the components being mixed. Little or no shrinkage occurs when 100% bark is mixed with bark of the same grade or when 100% sand is mixed with sand of the same grade because of the similarity of particle size of materials being mixed; however, as the percentage of sand mixed with bark is increased from 0% to 50%, loss of volume increases curvilinearly with increasing increments of sand (Fig. 1). The same response is obtained when sand is mixed with increasing increments of bark up to a 50:50 (v/v) mixture. Greatest volume loss occurs when the 2 components, bark and sand, are blended in equal volumes.

Actual and predicted BD decreased linearly as the percentage of sand was decreased from 100% to 0% (Fig. 2). Linear regression accounted for 99% of the variation. There was no significant difference between actual and predicted BD for any volume mixture of pine bark and sand. The near perfect relationship between predicted and observed BD values indicates the excellent reliability of the BD predictive equation under conditions of this experiment.

Application of the predictive equation to data reported in the literature (2, 5, 7, 9, 14) for media composed of components other than pine bark and sand yields results very similar to actual

Table 1. Particle-size distribution of pine bark and/or sand potting media used for bulk density determinations.

		U.S. std sieve series [mesh opening (mm) in parentheses]							
Sand (%)	Bark (%)	4 (4.76)	8 (2.38)	10 (2.00)	18 (1.00)	20 (0.84)	30 (0.60)	40 (0.42)	Receiver pan 0.42
					%/wt				
0	100	19.49	20.75	4.98	18.26	3.33	6.64	5.80	20.75
10	90	12.70	13.85	3.65	18.35	5.28	11.74	11.37	23.05
20	80	8.85	9.92	2.92	18.42	6.36	14.63	14.56	24.33
30	70	6.38	7.40	2.43	18.47	7.08	16.50	16.59	25.15
40	60	4.64	5.63	2.09	18.49	7.58	17.81	18.02	25.74
50	50	3.36	4.32	1.83	18.51	7.96	18.77	19.08	26.17
60	40	2.38	3.32	1.64	18.53	8.23	19.51	19.89	26.51
70	30	1.60	2.53	1.49	18.54	8.46	20.09	20.53	26.77
80	20	0.97	1.89	1.37	18.55	8.64	20.56	21.05	26.97
90	10	0.44	1.36	1.27	18.56	8.79	20.97	21.48	27.15
100	0	0	0.91	1.18	18.56	8.92	21.29	21.84	27.30

Table 2. Actual and predicted bulk density (BD) of selected container media (volume mixtures).

Medium (v/v)	Reference	Actual BD (gm/cc)	Percent shrinkage	Predicted BD (gm/cc)
Pine bark		0.340	---	---
Aged cinders		0.990	---	---
2:1 Pine bark/cinders	9	0.640	13.2	0.641
Peat		0.174	---	---
Pine bark		0.197	---	---
1:3 peat/pine bark	2	0.206	7.3	0.206
Mataura peat		0.110	---	---
Sawdust		0.140	---	---
1:1 M. peat/sawdust	5	0.130	3.8	0.129
Dipton peat		0.220	---	---
Sand		1.650	---	---
1:1 D. peat/sand	5	0.990	5.6	0.990
Mataura peat		0.110	---	---
Soil		1.160	---	---
1:1 M. peat/soil	5	0.810	21.6	0.809
Peat		0.059	---	---
Sand		1.630	---	---
2:1 peat/sand	7	0.600	3.0	0.600
Hauraki peat		0.134	---	---
Coarse perlite		0.204	---	---
3:1 H. peat/c. perlite	14	0.159	4.5	0.159

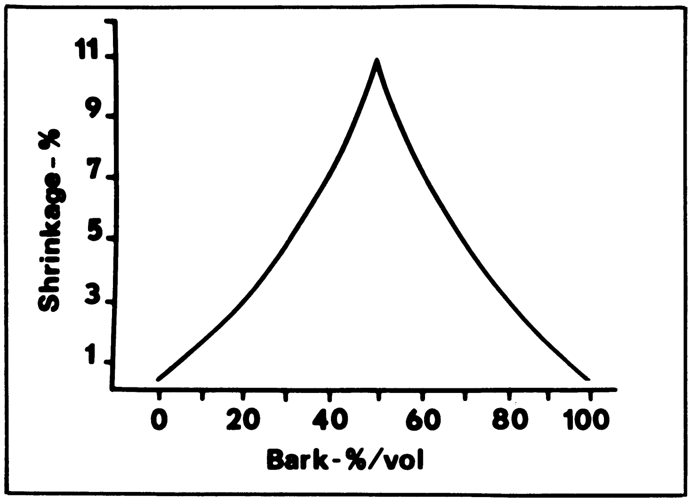

Fig. 1. Shrinkage curve for pine bark and/or sand potting media. Media of 0% bark to 50% bark: $\hat{Y} = 0.11 + 0.08\ B + 0.003\ B^2$, df = 57, $R^2 = 0.90$; Media of 50% bark to 100% bark: $\hat{Y} = 0.30 + 0.06\ S + 0.003\ S^2$, df = 57, $R^2 = 0.86$; B = % bark, S = % sand.

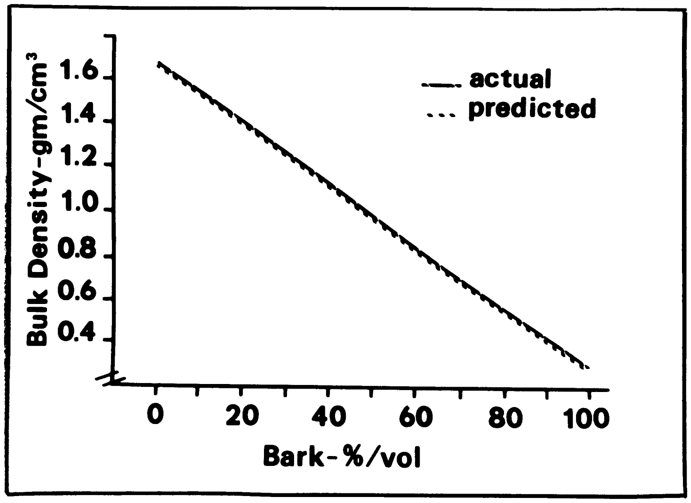

Fig. 2. Actual and predicted bulk densities of volume mixtures of pine bark and/or sand potting media. Actual: $\hat{Y} = 1.67 - 0.01\ X$, df = 107, $r = 0.995$. Predicted: $\hat{Y} = 1.65 - 0.01\ X$, df = 107, $r = 0.995$.

BD values reported by other investigators (Table 2). Thus, the devised equation is applicable to media other than bark and sand.

Can the predictive equation for a 2 component potting medium be modified to accommodate 3 or more components? It may be possible by restating equation 2 as

$$D_{mx} = \frac{(V_tC_1)(D_1) + \cdots\cdots\cdots + (V_tC_x)(D_x)}{V_t - S} \quad [3]$$

where: D_{mx} = predicted bulk density (gm/cm^3) of volume mixture; V_t = total sample volume; C_1 = volume percentage component 1; C_x = volume percentage component $_x$; D_1 = bulk density (gm/cm^3) component 1; D_x = bulk density (gm/cm^3) component $_x$; and S = percent shrinkage.

Computer modeling of potting media has been proposed by Pokorny (11). The basis for the proposal lies in the capability of predicting physical and chemical properties of media. Before computer modeling can become a reality, however, additional equations must be devised which reliably predict other physical and chemical properties.

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Predicting Harvesting Date of Processing Tomatoes by a Simulation Model

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Additional index words. Heat units, physiological day

Abstract. **A computer program was developed for predicting the times of emergence, flowering, turning stage, and harvesting of processing tomatoes. The program was validated and calibrated by using 1972-1980 tomato data from 44 fields at 2 locations in Israel. Predictions are based on accumulation of heat units defined in terms of "physiological days", where 1 physiological day is equivalent to a calendar day with a constant temperature of 26°C. The growing season was divided into 4 stages: from sowing to emergence, from emergence to flowering, from flowering to turning stage, and from turning stage to harvesting. Accumulation of physiological days during the first 2 stages is based on a linear function. During the last 2 stages, a quadratic function is used to calculate daytime heat units wherever the daily average temperature is above 20°. The maximum rate of development is at 26°. In the last stage, soil stress index also is taken into account. Use of the model makes it possible to predict the day of harvest with a precision of ±3 days, as compared with ±9 days when a daily mean systems is employed.**

The efficient operation of tomato processing plants requires the steady supply of tomatoes over an extended period of time. Planting on different dates can extend the harvest period. Knowledge of the influence of environmental factors on vegetative growth, fruit development, and ripening rate will permit a more precise manipulation of planting dates in different areas in order to ensure the continuity of fruit supply.

Prediction of plant development is based mainly on heat unit accumulation (3, 4, 11, 12, 13). The common method of calculating heat units is by means of the daily mean method, in which a day is the time unit and each degree above a base temperature has a linear effect on plant growth and on the accumulation of heat units. This can be expressed as:

$$\mathrm{HDU} = (\mathrm{TMAX} + \mathrm{TMIN})/2 - \mathrm{THMIN}$$

where HDU is the daily accumulation of heat units, TMAX is the daily maximum temperature, TMIN is daily minimum temperature, and THMIN is the base temperature. By this method, negative values are ignored, and the minimum daily accumulation is zero.

In all predictive methods, it is assumed that the plant must accumulate a certain number of heat units in order to complete a developmental stage. Reports differ, however, with regard to the base temperature required for predicting the harvesting date of processing tomatoes (4, 13). None of these methods shows any significant advantage over the actual counting of days. These methods do not take into account the possibility of different base temperatures for different developmental stages. Optimum,

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