3. Bar Tsur, A. 1977. High temperature effects on gas exchange characteristics, flowering and fruit set in tomatoes. MS Thesis, Hebrew Univ. of Jerusalem, Rehovot, Israel.
4. Behboudian, M. H. 1977. Water relation of cucumber, tomato and sweet pepper. Meded. Landhouwhogesch Wageningen 77:1–84.
5. Boyer, J. S. 1967. Leaf water potentials measured with a pressure chamber. Plant Physiol. 42:133–137.
6. Boyer, J. S. 1970. Leaf enlargement and metabolic rates in corn, soybean and sunflower at various leaf water potentials. Plant Physiol. 46:233–235.
7. Carlson, R. E., N. N. Nomen, O. Arjmond, and R. H. Shaw. 1979. Leaf conductance and leaf-water potential relationships for two soybean cultivars grown under controlled irrigation. Agron. J. 71:321–325.
8. Cerada, A., F. T. Bingham, G. J. Hoffman, and C. K. Kuszar. 1979. Leaf water potential and gaseous exchange of wheat and tomato as affected by NaCl and P levels in the root medium. Agron. J. 71:27–31.
9. Cutler, J. M. and D. W. Rains. 1977. Effect of irrigation history on responses of cotton to subsequent water stress. Crop Sci. 17:329–335.
10. De Roo, H. C. 1969. Leaf water potentials of sorghum and corn estimated with the pressure bomb. Agron. J. 61:969–970.
11. Fereres, E., E. Acevedo, D. W. Henderson, and T. C. Hsaio. 1978. Seasonal changes in water potential and turgor maintenance in sorghum and maize under water stress. Physiol. Plant. 44:261–267.
12. Hsiao, T. C. 1973. Plant response to water stress. Annu. Rev. Plant Physiol. 24:519–570.
13. Hsiao, T. C., E. Acevedo, E. Fereres, and D. W. Henderson. 1976. Water stress, growth and osmotic adjustment. Philos. Trans. Royal Soc. London B. 273:479–500.
14. Kaufman, M. R. and A. E. Hall. 1974. Plant water balance — Its relationship to atmospheric and edaphic condition. Agr. Meteor. 14:85–89.
15. McCree, K. J. 1974. Changes in the stomatal response characteristics of grain sorghum produced by water stress during growth. Crop Sci. 19:273–278.
16. Schacroft, R. W., E. R. Lemon, L. H. Allen, Jr., D. N. Steward, and S. E. Jensen. 1974. The soil-plant-atmosphere model and some of its predictions. In: J. F. Stone (ed.) Plant modification for more efficient water use. Agr. Meteor. 14:287–307.
17. Scholander, P. F., H. T. Hammel, E. D. Bradstreet, and E. A. Hemmengsen. 1965. Sap pressure in vascular plants. Science 148:339–347.
18. Turner, N. C. 1979. Drought resistance and adaptation to water deficits in crop plants. p. 343–372. In: H. Mussel and R. C. Stapler (ed.) Stress physiology of crop plants. Wiley, New York.

J. Amer. Soc. Hort. Sci. 106(6):736–741. 1981.

Physical Properties of Three Container Media and their Effect on Poinsettia Growth[1]

W.C. Fonteno, D.K. Cassel, and R.A. Larson[2]
North Carolina State University, Raleigh, NC 27650

Additional index words. water-holding capacity, bulk density, particle size, *Euphorbia pulcherrima*

Abstract. **Three fundamental different media 3 pine bark (≤ 6mm):1 sphagnum peat moss:1 concrete grade sand; 2 loamy soil: 1 peat moss:1 perlite; and a peat-lite mix, (Metro Mix 350) were characterized by available water-holding capacity, bulk density and particle size distribution. All 3 media provided adequate water-holding capacities for container production of 'Eckespoint C-1 Red' and 'Annette Hegg Diva' poinsettias (*Euphorbia pulcherrima* Klotzsch ex. Willd.). Total porosity declined and bulk density increased in all media 9 weeks after potting due to shrinkage but there were no additional changes after an additional 4 weeks. Airspace and water buffering capacities did not change during the 13-week period indicating the loss in total porosity resulted in a loss of easily available water. Water release had linear and nonlinear components with respect to moisture tension. Poinsettia root systems appeared to be extensive throughout the growing media; root distributions varied with cultivar and medium.**

Most greenhouse crops are grown in lightweight soilless media (16), which are combinations of 2 or more components of a limited selection, formulated to achieve desirable chemical and physical properties. There is no one optimum growing medium for all potted plants. Most container research has dealt with the relation of medium characteristics to optimum production (2, 8, 10, 12, 13, 15, 22). Potting media vary widely with respect to water retention (21). Media containing sphagnum peat moss, with a high water-holding capacity, caused plants to wilt more quickly than a medium containing pine bark, with a lower water-holding capacity (1).

Container media are characterized by determination of phase-distribution including the solid, water, and air volumes at different moisture conditions. These can be determined by developing a water-release curve (7, 19). Low moisture tensions (MT) are important for floricultural crops since the amount of moisture held at tensions exceeding 100 cm can greatly reduce plant growth rate (6). Puustjarvi and Robertson (20) believe that most of the moisture utilized by greenhouse crops is held at tensions between 10 and 100 cm.

The purpose of this study was to determine the water holding characteristics of 3 fundamentally different growing media, the changes which occur in their water-holding characteristics during poinsettia production, and the effect of these media on poinsettia root and shoot growth.

Materials and Methods

Single cuttings of 'Eckespoint C-1 Red' and 'Annette Hegg Diva' poinsettias were inserted in Oasis root cubes (phenol formaldehyde plastic blocks) on August 6 and August 9, respec-

[1]Received for publication January 17, 1981. Paper No. 6757 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, N.C. Partially funded by a grant from the Fred C. Gloeckner Foundations, Inc. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of products named, nor criticism of similar ones not mentioned.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[2]Assistant Professor, Department of Horticultural Science; Professor, Department of Soil Science; Professor, Department of Horticultural Science, respectively. The authors wish to acknowledge Paul Ecke Poinsettia Inc., Encinitas, Calif. for the donation of poinsettia cuttings and W.R. Grace Co., Cambridge, Mass., Colburn Lumber Co., Windsor, N.C. and Hardin's Greenhouses, Liberty, N.C. for the donation of media.

tively, were potted in 16.5 cm plastic azalea pots on September 11, 1979, and pinched on September 15.

Three media were selected to provide a range of components commonly used to produce poinsettias in North Carolina (Table 1). Nine plants of each cultivar were grown in each of the 3 media, each treatment was replicated 4 times. At potting time, 24 pots filled with each medium but without plants were randomly placed on greenhouse benches among the pots containing plants and treated identically. Eight fallow pots of each medium were removed immediately after potting, after 9 and after 13 weeks of production to determine porosity and water-holding characteristics.

Plants were grown under greenhouse conditions recommended by Larson et al. (11) without growth regulators. About 180 ml of water was applied daily to each container by hand. Near the end of the experiment, plants were watered twice daily. Plant height was measured from the rim of the pot to the apex of the tallest shoot 9 and 13 weeks after potting. At the end of production (13 weeks), 5 plants of each cultivar/medium combination were visually compared for root distribution. Tops were removed and the medium was cut longitudinally in half and left to dry overnight. Photographs were taken of root distribution surrounding the container medium and on the longitudinally cut surface.

Various parameters were obtained from a 347.5 cc cylindrical (diameter = 7.62 cm, height = 7.62 cm) core of medium taken from the center of each fallow pot. The core was seated on the porous plate of a Kimax 600 ml 90 F Buchner filter funnel and saturated with water by slowly adding water over a period of 12 to 24 hr between the funnel wall and the outside of the sample retaining ring. An airtight lid was placed on top of the funnel and positive air pressures were applied in increments which resulted in the following pressures at the medium core center: 4, 10, 20, 40, 60 and 100 cm (H_2O). Use of this device gives identical results to those obtained using a tension table. After drainage ceased after applying each pressure increment, i.e., at equilibrium, the volume of outflow water was recorded. Normally a period of 24 hr was required to establish equilibrium for each pressure. After measurement at 100 cm MT was completed, each core was removed and its bulk density determined by calculating the volume of each core and weighing each core after drying 24 hr at 105°C. One core was taken for each of 8 replicate pots per medium per sampling time.

Table 1. Particle size distribution of 3 potting media.[z]

Particle size (mm)	Particle size distribution (% of dry wt)					
	Medium B		Medium S		Medium M	
	Mean	SD	Mean	SD	Mean	SD
>6.4	2.10	1.01	9.16	3.48	1.42	0.18
6.4-3.2	6.55	2.06	16.93	1.66	8.26	0.53
3.2-2.0	4.92	0.85	6.56	1.25	8.79	0.73
2.0-1.0	22.47	2.34	22.57	2.61	28.50	1.71
1.0-0.5	33.19	0.85	22.57	0.96	27.84	1.00
0.5-0.25	21.27	3.21	11.27	0.61	13.18	1.49
0.25-0.105	7.40	1.71	6.31	0.83	8.39	0.72
<0.105	2.10	0.63	4.88	0.86	3.63	0.63

[z]Medium B = 3 composted pinebark (<6mm): 1 Canadian sphaghum peat moss: 1 concrete grade sand (by volume).
Medium S = 2 loamy soil: 1 sphagnum peat moss: 1 sand: 1 perlite (by volume).
Medium M = Metro Mix 350 (a commercially available mix consisting of #3 grade vermiculite, Canadian sphagnum peat moss, and processed pinebark ash, the formulation of which is proprietary to W.R. Grace Co.).

DeBoodt and Verdonck (7) have introduced terms to describe moisture release curves for container media. Total porosity (TP) is defined as the moisture content at zero pressure. At this pressure, all pores are filled with water. Airspace (AS) is defined as the volume percent difference between TP and the moisture content at 10 cm MT. Easily available water (EAW) is the quantity of water released between MTs of 10 and 50 cm. This optimally represents 75-90% of the total available water in container media. Water buffering capacity (WBC) is the amount of water released between 50 and 100 cm MT and is considered a measure of water reserve; 4-5% by volume is considered optimal. Difficultly available water (DAW) is defined as the volume percent difference between 100 and 15,000 cm MT. Water held at MT greater than 15,000 cm is considered unavailable to plants. Water content values for 50 cm pressure were calculated and are the means of water content measured at 40 and 60 cm.

Particle size determinations were made using four 100 g air-dried samples of each medium placed in a series of U.S. Standard sieves on a mechanical shaker for 3 min at 30 shakes per minute.

Results and Discussion

Particle size distribution. Medium S had the greatest percentage of particles >3.2 mm (Table 1) due to soil aggregates which were not present in the other 2 media. Particle size distribution between 2.0 and 0.5 mm was fairly uniform among the 3 media. The percentage of particles between 0.5 and 0.25 mm was nearly twice as great for Medium B as in the other 2 media, but distribution below 0.25 mm was similar among the 3 media. Media M and S had similar particle distributions except for the large percentage of aggregates in Medium S. Over 75% of the particles in Medium B was distributed between 2.0 and 0.25 mm.

Water-holding characteristics. The moisture release curve for Medium B, sampled 13 weeks after potting (Fig. 1A) is presented in the graphical style of DeBoodt and Verdonck (7). This type of curve actually describes the water-releasing characteristics of a sample medium. Fig. 1B, derived from the same data as Fig. 1A, describes the water-holding characteristics of Medium B. We prefer the Fig. 1B form of presentation because the water content in the medium can be easily read at any given MT.

Moisture retention curves for the 3 media immediately after potting the poinsettias and before irrigation are shown in Fig. 2. Medium S held less water between MTs of 0 and 4 cm than the other media (Table 2). Medium M retained the most water at 10 cm MT. Media S and M had similar water retention characteristics from 40 to 100 cm MT; Medium B retained less water between these tensions. Considerable shrinkage of each medium occurred as water was removed during the measurement period; all water content data reported in Fig. 2 were corrected for this shrinkage. Medium S shrank 11.2% by volume, B shrank 6.6% and M shrank 4.8%.

Moisture retention curves 9 weeks after potting were somewhat different (Fig. 3). Medium B showed a reduction in water-holding capacity at lower pressures (0 to 10 cm) but generally had higher water-holding capacities at higher MT. This observation results from a reduction in macropores coupled with an increase in the volume of micropores due to shrinkage (3). This same trend occurred for Medium S, whereas Medium M exhibited a general increase in water-holding capacities at all MTs. The water-holding characteristics of Media M and S were similar as in the initial curves (Fig. 2) while B showed lower moisture retention values at the higher MT. Medium shrinkage during moisture retention measurement of the samples at 9 weeks was less than shrinkage during similar measurements for the initial core samples. Shrinkage for Medium M, B, and S were 7.8, 26.1, and 18.3% by volume, respectively.

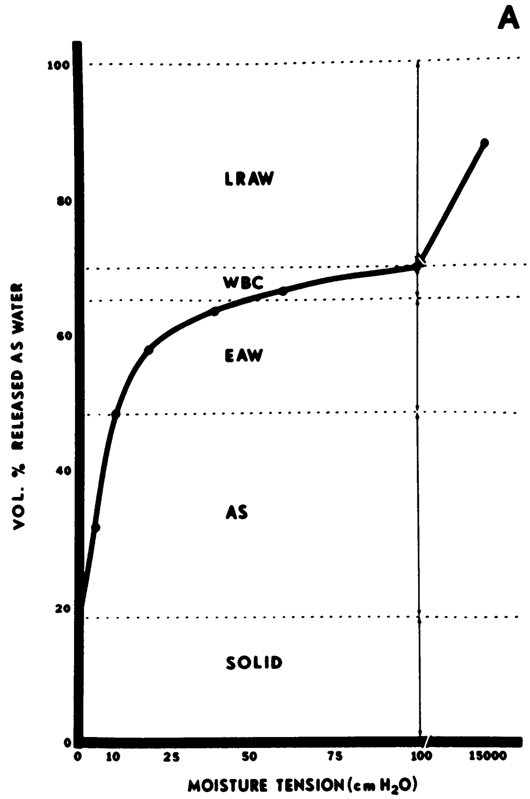

Fig. 1A. Moisture release curve of Medium B (see Table 1 for composition) 13 weeks after potting, showing percent total medium volume of solid material (SOLID), airspace (AS), easily available water (EAW), water buffering capacity (WBC), and less readily available water (LRAW).

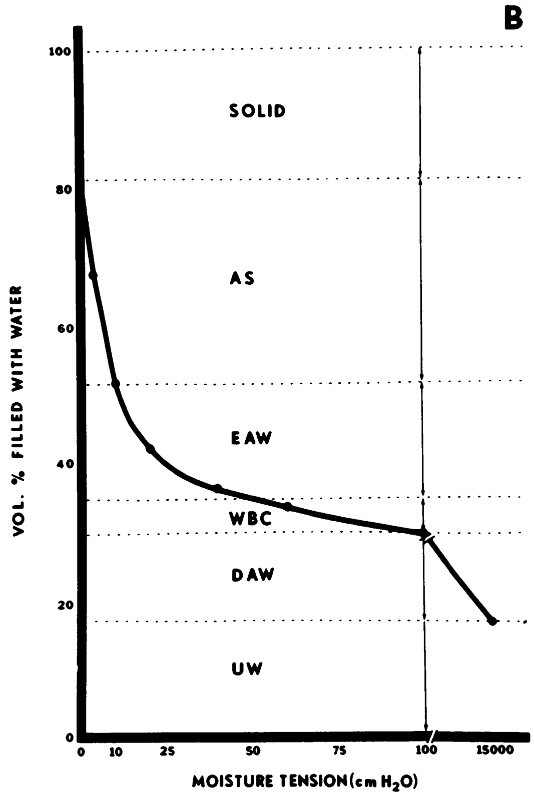

Fig. 1B. Moisture retention for medium B (see Table 1 for composition) 13 weeks after potting, showing percent total medium volume of solid material (SOLID), airspace (AS), easily available water (EAW), water buffering capacity (WBC), difficulty available water (DAW), and unavailable water (UW).

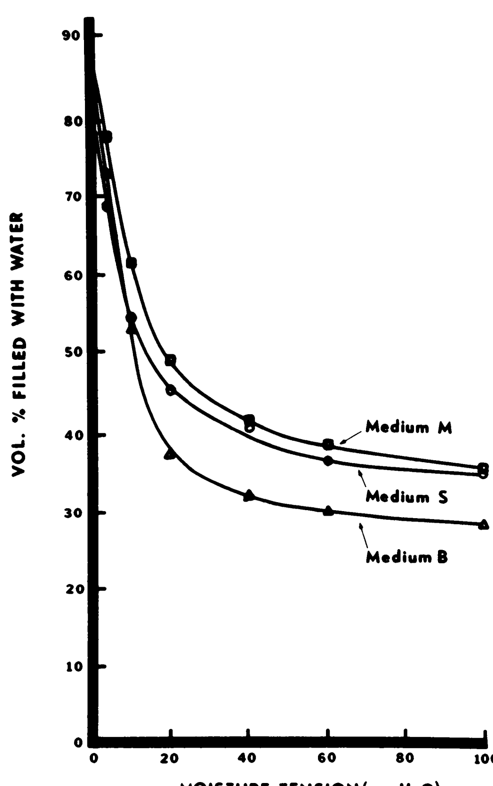

Fig. 2. Moisture retention curves for 3 media immediately after potting (see Table 1 for media composition).

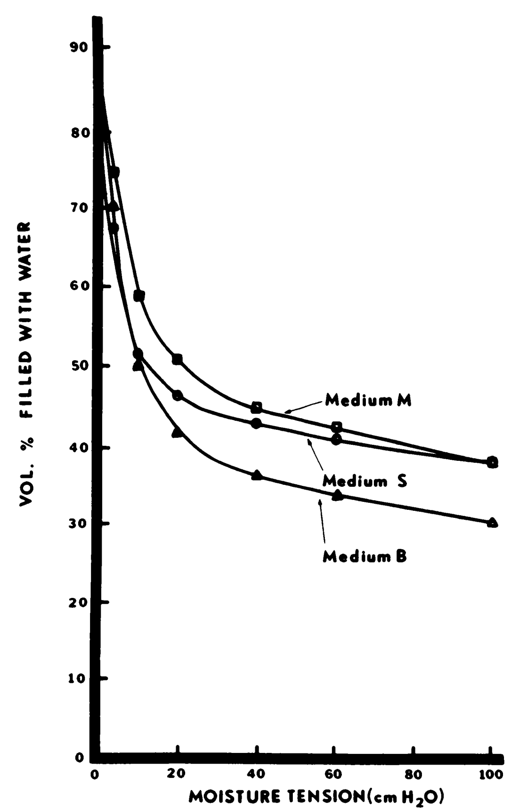

Fig. 3. Moisture retention curves for 3 media 9 weeks after potting (see Table 1 for media composition).

Moisture retention curves for each medium after 13 weeks were similar to those measured 9 weeks after potting. The relationships among the curves indicated that the water-holding characteristics of each of the 3 media did not change after 9 weeks. This stablization of water retention may be reached sooner than 9 weeks.

Regression analysis indicated that the relationship of water content to MT for these media have both linear and nonlinear components (Table 2). Moisture content for all 3 media appeared generally to be linear from 0 to 20 cm MT and nonlinear from 20 to 100 cm MT. The degree of nonlinearity varied with both medium type and time in production. The linear predicted values for 20 cm were closer to the measured value and therefore would be preferable to the nonlinear value.

We recommend that horticulturists discuss water-holding characteristics of media using the concepts postulated by DeBoodt and Verdonck (7). The optimum levels of TP, AS, EAW, and WAC defined by Deboodt and Verdonck were subsequently used by Bunt (3, 4), Maas and Adamson (13), Goh and Haynes (9), Mastalerz (14), Prasad (17, 18) and the present study. The relationship of TB, AS, EAW, WBC, DAW, and unavailable water to the moisture retention curve is demonstrated in Fig. 1B for Medium B after 13 weeks.

Total porosity. Immediately after potting, Medium S had a lower TP than the other media and maintained this relationship throughout the 13-week period (Table 3). Media M and B showed similar TP after potting but TP of Medium B was less than M at both 9 and 13 weeks. Total porosity did not change in any medium from 9 to 13 weeks of production. Compared with the TP value for a theoretical ideal substrate used by Prasad (17), Media B and M approached ideal whereas S was low.

Airspace. Generally, AS remained the same for each medium throughout the study with Medium B having the highest values in all but one case. Therefore, the change in TP cannot be attributed to a change in AS. All 3 media showed AS values within the range for an ideal substrate (20-30%).

Easily available water. Media B and M had higher EAW values than S. The EAW for all 3 media was lower at 9 and 13 weeks after potting. This decrease in EAW could account for some of the loss in TP during production. Media B and M showed EAW values close to ideal immediately after potting, dropping significantly thereafter. After 13 weeks, Medium S had considerably lower EAW, being about ⅓ to ½ of the ideal (20–30%).

Water buffering capacity. Medium M had the highest WBC throughout the 13-week study. Media B and S increased in WBC

Table 2. Predicted and measured water content at specific moisture tensions for 3 media and 3 sampling times from linear and quadratic models.[z]

Medium	Weeks after potting	Model	Water content (% by vol) 0	4	10	20	40	60	100	r^2
B[x]	0	Predicted								
		Linear	86.4	71.6	54.0	37.4				0.98
		Quadratic				35.8	33.5	31.3	26.8	0.75
		Measured[y]	85.7 bc	73.2 c	53.0 c	37.6 e	32.1 d	29.8 e	28.0 c	
	9	Predicted								
		Linear	83.2	67.7	51.1	41.4				0.98
		Quadratic				40.2	37.4	34.6	29.0	0.84
		Measured	82.1 d	70.0 d	49.7 d	41.7 d	36.2 c	33.5 d	30.0 c	
	13	Predicted								
		Linear	81.4	67.3	52.1	41.9				0:94
		Quadratic				40.5	37.7	34.9	29.3	0.85
		Measured	81.2 d	67.8 e	51.8 c	42.0 d	36.5 c	33.7 d	30.2 c	
S	0	Predicted								
		Linear	81.6	68.5	54.4	45.5				0.99
		Quadratic				44.0	41.4	38.9	33.8	0.77
		Measured	81.5 d	68.8 de	54.3 c	45.6 c	40.9 b	36.5 c	35.1 b	
	9	Predicted								
		Linear	78.7	65.7	52.3	46.1				0.97
		Quadratic				45.6	43.7	41.7	37.8	0.63
		Measured	78.1 e	67.0 e	51.5 cd	46.3 c	43.2 ab	41.2 a	38.2 a	
	13	Predicted								
		Linear	76.5	63.7	50.6	45.5				0.84
		Quadratic				44.4	42.4	40.3	36.3	0.86
		Measured	77.3 e	61.9 f	51.7 cd	45.3 c	41.6 b	39.8 ab	36.7 ab	
M	0	Predicted								
		Linear	85.8	75.6	62.9	48.7				0.97
		Quadratic				46.6	43.4	40.2	33.8	0.84
		Measured	84.8 c	77.8 a	61.5 a	49.0 b	41.4 b	38.5 bc	35.2 b	
	9	Predicted								
		Linear	88.7	74.1	58.8	50.7				0.91
		Quadratic				49.2	46.1	43.1	37.0	0.89
		Measured	88.5 a	74.5 bc	58.5 b	50.8 a	44.7 a	42.1 a	37.9 a	
	13	Predicted								
		Linear	87.8	75.8	62.0	50.2				0.98
		Quadratic				49.1	46.3	43.6	38.1	0.88
		Measured	87.7 ab	76.0 ab	61.9 a	50.5 ab	45.2 a	42.4 a	39.0 a	

[z]Linear models calculated from 0 to 20 cm moisture tension (H_2O). Quadratic models calculated from 20-100 cm moisture tension (H_2O)
[y]Measured means within a column separated by Duncan's multiple range test, 5% level.
[x]See Table 1 for media composition.

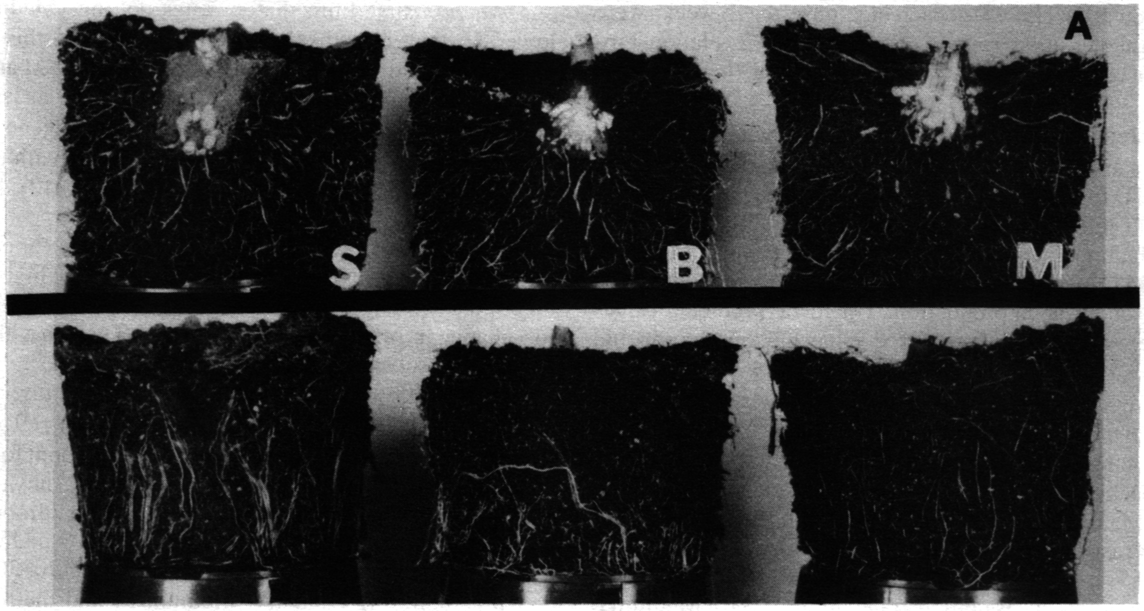

Fig. 4A. Root distribution of 'Annette Hegg Diva' poinsettias surrounding the container medium (lower) and on the longitudinally cut surface (upper) of Media S, B, M (see Table 1 for media composition).

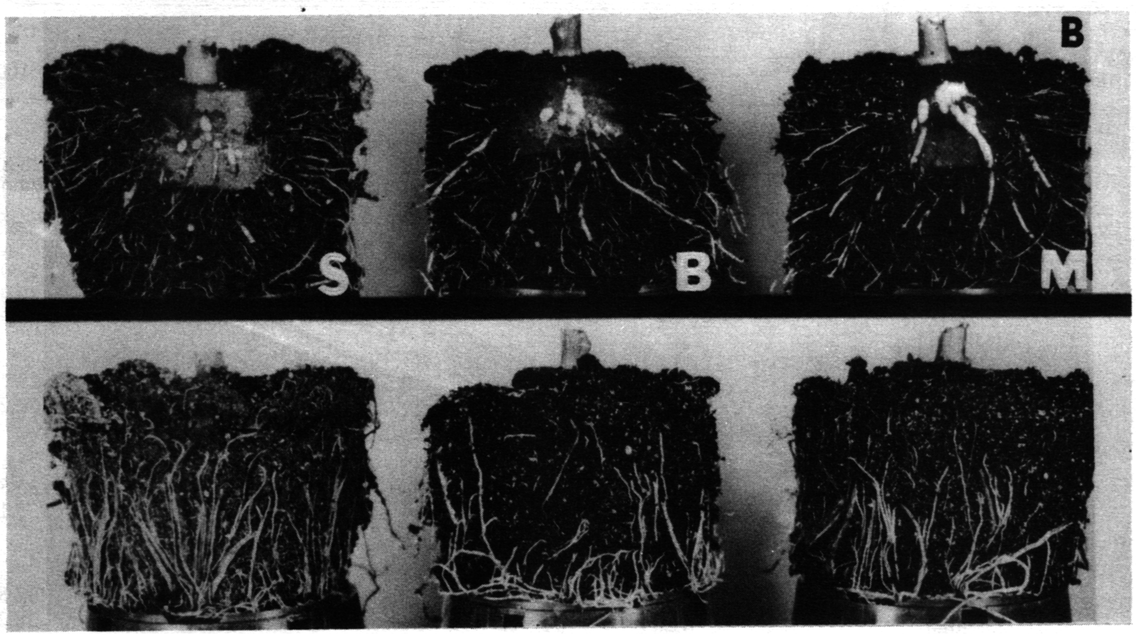

Fig. 4B. Root distribution of 'Eckespoint C-1' poinsettias surrounding the container medium (lower) and on the longitudinally cut surface (upper) of Media S, B, M (see Table 1 for media composition).

during the same period. The WBC at 9 and 13 weeks for all 3 media fell within the range for an ideal substrate (Table 3).

Bulk density. The bulk density (BD) values for the 3 media immediately after potting were S>B>M (Table 3); a relationship which persisted throughout the study. Bulk density of each mix increased during the 9-week period following potting but did not change thereafter. This initial increase and subsequent stablization of BD emulates the settling or shrinkage loss found in the moisture release determinations. Shrinkage showed a very high negative correlation (0.85 to 0.95, 1% level) to BD for all 3 media.

Effects on poinsettia growth. High quality poinsettias were produced in all 3 media. After 9 weeks 'Annette Hegg Diva' grown in Medium B were shorter than those for the other 2 media (Table 4); this difference persisted after 13 weeks of production. 'Ekespoint C-1 Red' were shorter in B than in S and S produced the tallest plants after 13 weeks.

Examination of the root systems showed differences between cultivars and media with respect to root distribution (Figs. 4A and 4B). Both cultivars produced healthy, vigorous root systems in all 3 media. Root systems of 'Eckespoint C-1 Red' had larger diameter roots that were less fibrous and fewer in number than 'Annette Hegg Diva'. For both cultivars a larger portion of root system was found surrounding the medium mass for Medium S than for B and M. The more fibrous root system of 'Annette Hegg Diva' plants was more evenly dispersed throughout the medium for Media B and M (Fig. 4A); the larger, less fibrous roots of 'Eckespoint C-1 Red' plants were more equally distributed throughout the medium

Table 3. Percent volume attributed to total porosity (TP), airspace (AS), easily available water (EAW), water buffering capacity (WBC), and bulk density (BD) of 3 container media for 3 sampling times.

Time after potting (weeks)	Medium[z]	TP (%)	AS (%)	EAW (%)	WBC (%)	BD (g/cm^3)
0	B	85.7 ab[y]	32.7 a	22.0 a	3.1 e	0.355 d
	S	81.5 d	27.2 bc	15.6 c	3.7 d	0.461 b
	M	84.8 bc	23.3 d	21.6 a	4.8 b	0.185 f
9	B	82.1 cd	32.4 a	14.9 c	4.7 b	0.395 c
	S	78.1 e	26.6 bcd	9.3 d	4.3 bc	0.507 a
	M	88.5 a	30.0 ab	15.2 c	5.5 a	0.211 e
13	B	81.2 d	29.4 ab	16.7 bc	4.8 b	0.388 c
	S	77.3 e	25.6 cd	11.0 d	4.0 cd	0.500 a
	M	87.7 ab	25.8 cd	18.1 b	4.8 b	0.213 e
Ideal substrate[x]		85.0	20-30	20-30	4-10	------

[z]See table 1 for composition of media.
[y]Mean separation by Duncan's multiple range test, 5% level.
[x]Theoretical values described by DeBoodt and Verdonck (7).

Table 4. Height of 'Eckespoint C-1 Red' and 'Annette Hegg Diva' poinsettias after 9 and 13 weeks of growth in 3 container media.[z]

Cultivar	Medium	Height (cm) 9 weeks	13 weeks
Annette Hegg Diva	B	51 b[y]	60 b
	S	56 a	64 a
	M	55 a	65 a
Eckespoint C-1 Red	B	40 d	44 d
	S	44 c	49 c
	M	42 cd	45 d

[z]See Table 1 for composition of media.
[y]Means separated by Duncan's multiple range test, 5% level.

in these 2 media. The increase in the number of roots found with Media M and B may be due in part to the increased porosity found in these media. This suggests that the common method of checking root growth during production, i.e. removing the pot and visually examining the outside of the rootball, may not give a correct picture of root growth. Root growth within the medium may be extensive with proportionately fewer roots appearing on the outside of the rootball.

These data on media and observations on root distribution indicate that all 3 media provided adequate moisture holding capacities for production of poinsettias. During production TP in these media decreased slightly. Since both AS and WBC were essentially unchanged during production, the loss in TP may have been caused by a loss of EAW. This would suggest that frequent overhead irrigation may lead to compaction which reduced the available water most critical to optimal growth. Medium S with lower TP and EAW may require more careful regulation of watering. The greater BD of Medium S might be an important consideration in shipping since increased weight increases freight charges. Conversely, Medium S may result in increased plant stability.

Literature Cited

1. Beardsell, D.V., D.G. Nichols, and D.L. Jones. 1979. Water relations of nursery potting media. Sci. Hort. 11:9-17.
2. Bunt, A.C. 1971. The use of peat-sand substrates for pot chrysanthemum culture. Acta Hort. 18:66-74.
3. Bunt, A.C. 1974. Some physical and chemical characteristics of loamless pot-plant substrates and their relation to plant growth. Acta Hort. 37:1954-1965.
4. Bunt, A.C. 1976. Modern potting composts. Pa. State Univ. Press, University Park.
5. Cappaert, J., O. Verdonck, and M. DeBoodt. 1974. Bark waste as a growing medium for plants. Acta Hort. 37:2013-2022.
6. DeBoodt, M., and O. Verdonck. 1971. Physical properties of peat and peat-moulds improved by perlite and foam-plastics in relation to ornamental plant-growth. Acta Hort. 18:9-25.
7. DeBoodt, M, and O. Verdonck. 1972. The physical properties of the substrates in horticulture. Acta Hort. 26:37-44.
8. Frye, S. 1980. The effects of physical properties of oak hardwood bark pot media on the growth and development of *Chrysanthemum morifolim* Ramat. MS Thesis, Univ. of Missouri, Columbia.
9. Goh, K.M. and R.J. Haynes. 1977. Evaluation of potting media for commercial nursery production of container-grown plants. I. Physical and chemical characteristics of soil and soilless media and their constituents. N. Zeal. J. Agr. Res. 20:363-370.
10. Kaukovirta, E. 1972. Bark-humus as an alternative to peat and soil in the production of cut flowers. Acta Hort. 26:119-124.
11. Larson, R.A., J.W. Love, D.L. Strider, R.K. Jones, J.R. Baker, and K.F. Horn. 1978. Commercial poinsettia production. N.C. Agr. Ext. Serv. Bul. AG-108.
12. Love, J.W. 1978. Basics of bark media. Ohio Florists' Assoc. Bul. 584, June. p. 11-12.
13. Maas, E.F. and R.M. Anderson. 1975. Peat, bark, and sawdust mixtures for nursery substrates. Acta Hort. 50:147-151.
14. Mastalerz, J.W. 1977. The greenhouse environment. Wiley, New York.
15. Poole R.T. and W.E. Waters. 1972. Evalution of various potting media for growth of foliage plants. Proc. Fla. State Hort. Soc. 85:395-398.
16. Poole, R.T. and C.A. Conover. 1979. Light weight soilless mixes. Ornamentals South. April. p. 26-28.
17. Prasad, M. 1979. Physical properties of medial for container-grown crops. I. New Zealand peats and wood wastes. Sci. Hort. 10:317-323.
18. Prasad, M. 1979. Physical properties of media for container-grown crops. II. Peat mixes. Sci. Hort. 10:325-330.
19. Puustjarvi, V. 1974. Physical properties of peat used in horticulture. Acta Hort. 37:1922-1929.
20. Puustjarvi, V. and R.A. Robertson. 1975. Physical and chemcial properties. p. 23-38. In: D.W. Robinson and J.G.D. Lamb (eds.) Peat in horticulture. Academic Press, London.
21. Spomer, L.A. 1974. Optimizing container soil amendment: the "threshold proportion" and prediction of porosity. HortScience 9:532-533.
22. Stern, J.H., J.W. White, R.L. Cunningham, and R.H. Cole. 1974. Trickle irrigation and media effects on growth of *Chrysanthemum morifolium* Ramat. Acta Hort. 37:1975-1982.