These results show that early root initiation from immersion in water is a reproducible result for poinsettia, honeysuckle, and rose. The variable response of holly and nonresponse of juniper indicate that all the conditions for a favorable response may not be understood or that some species may be unresponsive.

Ventilated high humidity propagation appears to have promising commercial applications for propagation, and immersion, at least for some species, may be a beneficial pretreatment for early rooting of cuttings.

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RICHARD WOLFF: Just a comment on Dr. Milbocker's paper. We took cuttings of Japanese red maple this past year from plants that were well hydrated from irrigation. Those cuttings rooted 100% as usual. We also took cuttings from our tree farm. We had a drought this past summer and did not hydrate the cuttings from the tree farm and the percentage fell back to 50%. We came to the conclusion that the hydrated trees gave us better rooting.

IMPROVING MEDIA AERATION IN LINER AND CONTAINER PRODUCTION

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Considerable information has been published regarding container media ingredients, their properties and their effects on root growth (1,2,3,4,6). Most modern day propagators use a soilless medium during propagation and/or for subsequent growing on in containers. Every medium has different physical and chemical properties that will affect rooting, and subsequent plant growth and development. In addition, a medium that may be best (poorest) for rooting may be the poorest (best) for growing on in larger containers (5). Consequently, finding a medium that would meet all of a growers specific requirements for both propagation and growing on may be difficult.

Optimum soilless medium properties alone will not eliminate all production problems, but understanding physical and chemical properties is a key component to improve rooting and subsequent plant growth. In addition, utilizing these factors will assist a grower in evaluating the cost benefits of a particular medium.

Some suggested medium standards used at Studebaker Nurseries are listed in Table 1. These chemical and physical standards should only be considered as general guidelines. Since the organic component(s) comprises 50 percent or more by volume of our various media, we generally are not as concerned with the chemical properties in a medium during its initial development. Once our medium has been formulated, we then will adjust cultural practices to attain proper chemical requirements, e.g., adjustments in medium pH. In the following brief discussion about some of the physical properties of a container medium, keep in mind that these properties are closely related. A change in any one medium ingredient can affect one or more other properties.

Table 1. Some suggested media standards used at Studebaker Nurseries.

Property	Comments
Chemical	
pH	4.5 to 6.5, preferred 5.5 to 6.5
Buffer capacity	As high as possible
Soluble salts	*400 to 1000 ppm (1 soil: 2 water* by volume)
Cation exchange capacity	25 to 100 meg/liter
Physical	
Bulk density	0.3 to 0.80 g/cc[3] (dry) or 0.60 to 1.15 g/cc (wet)
Air-filled porosity	15 to 40% by volume, ideally 20 to 25% range
Water holding capacity	20 to 60% volume after drainage
Particle stability	Materials should resist decomposing quickly. Decomposition can alter other media components.

Pore space is extremely important in a container medium and the amount required varies by species. Table 2 lists the approximate percent air space requirements of some selected ornamentals (7). The bottom line is that each kind of plant has its own minimum oxygen requirement below which a plant cannot root and absorb water and nutrients for proper growth. Also, respiring roots emits carbon dioxide and, in a poorly aerated medium, carbon dioxide can reach toxic levels if insufficient air exchange is lacking between the medium and atmosphere.

Table 2. Approximate root aeration requirements of some selected ornamentals.[1]

Air space requirements[2]			
Above 20%	10 to 20%	5 to 10%	2 to 5%
Azalea	African violet	Camellia	Conifer
Fern	Begonia	Chrysanthemum	Carnation
Orchid	Foliage plants	Gladiolus	Geranium
	Gardenia	Hydrangea	Rose
	Gloxinia	Lily	Stocks
	Heather	Poinsettia	
	Rhododendron		
	Snapdragon		

[1]Adapted from: Criteria for Selection of Growing Media for Greenhouse Crops, *J.W. White, Penn. Ag. Expt. St. Journal Series* No. 4574
[2]Air space requirement after 24 hours of drainage.

During propagation, we try to keep our total medium porosity between 40 and 60%, and air space between 15 and 25 percent following 24 hours of drainage. We have found that as we approach the 60% porosity level, our medium tends to become too loose. Consequently, there is insufficient contact between the cutting and rooting medium, thus reducing rooting. We try to hold this porosity range through our liner stage of production which includes all pot sizes up to 938 ml (1 quart) volume.

A second medium property closely related to porosity is bulk density. Bulk density expresses soil weight per unit volume (g/cc) and takes into consideration solids and pore spaces between particles. A high bulk density generally indicates a "tight" medium and a low one indicates an open medium. Desirable bulk densities in field soils should be somewhere between 1.25 and 1.50 g/cc, which is considerably higher than what we prefer to have in our propagation or container medium (Table 1). We have found that *media with bulk densities of* between 0.8 and 1.0 g/cc (wet) are ideally suited for our propagation and liner production phases.

During our liner stage of production in 5 to 10 cm (2 to 4 in.) diameter pots, additional weight is often needed to prevent plants from tipping over in the wind. Maintaining bulk densities in the range of 0.8 to 1.0 g/cc, gives our containers additional ballast. The key to increasing ballast is to do so without drastically reducing porosity. At first, we often added sand to our media. Unfortunately, as we increased the amount of sand in our media to sufficient quantities for ballast, we did so at the expense of reducing percent air space. This reduction was sufficient to affect rooting of a number of kinds of plants.

We had been quite satisfied with the use of coarse horticultural grades of perlite for improving media porosity and drainage. However, in fog propagation, using a small container (approximately 100 ml volume), our peat and perlite 1:1 medium was holding too much moisture. Furthermore, perlite in our operation is messy to use, expensive, and requires a special covered storage area.

To correct our production problems, we set out to find a medium component that could add ballast without substantially reducing pore space, was easier to use and store, and was less expensive. In our container operation, we were using a 9.5 mm (3/8 in.) diameter expanded shale product for increasing ballast. We asked the manufacturer to produce a smaller particle size product comparable to the particle sizes found in coarse horticultural grades of perlite. A comparison of particle sizes between a coarse horticultural grade of perlite we use and the expanded shale product is shown in Table 3. The expanded shale product compares favorably with the perlite. The biggest difference between the two products is the quantity of very fine particle sizes which are retained on the No. 50 and No. 100 screens and in the remaining pan material. These particle sizes generally fall into the category of dust. The perlite is comprised of 4% dust by weight while the expanded shale product has approximately 1% dust by weight. This reduction in dust substantially reduced a major handling problem we normally encounter with perlite.

Table 3. Comparison of particle sizes between a coarse horticultural grade of perlite and expanded shale manufactured to similar particle size.

		Expanded shale[1]			Perlite[1]		
		Retained (%)		Passed (%)	Retained (%)		Passed (%)
Sieve no.	Screen size (mm)	Wt.	Cumulated wt.		Wt.	Cumulated wt.	
4	4.75	0	0	100	1.3	1.3	98.7
8	2.36	64.7	64.7	35.3	40.9	42.2	57.8
16	1.18	33.8	98.5	1.5	51.5	93.7	6.3
30	0.6	0.8	99.3	0.7	1.4	95.1	4.9
50	0.3	0.1	99.4	0.6	0.4	95.5	4.5
100	0.15	0.1	99.5	0.5	0.2	95.7	4.3
Pan	-	0.5	100	0	4.3	100	-

[1]Mean of 3 replications.

To compare the performance of the products as media components, perlite and expanded shale were individually mixed with sphagnum peat (1:1, v/v) and used to fill containers of two different sizes to approximate potting capacities of 94 and 770 ml. The resulting physical properties of each medium are listed in Table 4. In the 94 ml medium volume, total porosity, and water holding capacity between the peat-expanded shale and peat-perlite medium differed substantially. The peat-expanded shale medium's total porosity and water holding capacity were 11 and 22% less, respectively, than the same properties in the peat-perlite medium. This was desirable since we were trying to find a medium that was tighter and held less moisture during its use in fog propagation. In addition, these reductions in porosity and water holding capacity did not occur at the expense of reducing airspace. Both media had a similar percent air space after 24 hours of drainage. As volume increased from the 94 to 770 ml, the differences in water holding capacity of each became less. Because of the increased height of the larger container, additional water held in the peat-perlite medium was able to drain. There was very little difference in water holding capacity of the peat-expanded shale medium in either volume container.

The two media also differed substantially in their bulk densities. The peat-expanded shale medium was twice as heavy as the peat-perlite medium (Table 4). This provided the additional ballast we were seeking, while maintaining acceptable levels of percent airspace. The additional weight, of course, may be undesirable with respect to increasing shipping weight.

Table 4. Comparison of media physical properties using expanded shale or perlite — by itself or in combination with sphagnum peat in two different containers.[1]

		Media volume					
		94 cc			770 cc		
Media (V/V)	[2]Bulk density g/cc	Total porosity (%)	[3]Air space (%)	Water holding capacity (ml)	Total porosity (%)	Air space (%)	Water holding capacity (ml)
Peat (Pt)	1.06	72	20	52	63	17	46
Perlite (P)	0.34	71	50	21	67	49	18
Expanded shale (ES)	0.98	50	30	20	43	32	11
1 Pt: 1 P	0.54	66	22	44	60	23	37
1 Pt: 1 ES	0.94	55	21	34	54	18	40

[1]All data mean of 3 replications.
[2]Bulk density is wet bulk density; determined 24 hrs. after containers had initially been saturated and drained.
[3]Percent air space was determined after medium had been initially saturated and then drained for 24 hours.

To further test the performance of each medium we evaluated the rooting and subsequent growth of cuttings direct stuck at various times throughout the summer of 1985, into 5 × 5 × 6.3 cm (2×2×2.5 in.) containers (157 ml volume). For each kind of plant, equal numbers (ranging between 100 and 800 were stuck in both the peat and perlite, and peat and expanded shale media. All cuttings were placed in a fog propagation system until rooted. Following rooting, all plants were grown under 50% shade for the remainder of the summer season. On September 5, 1985, the percent rooting was determined and a visual analysis of the root system's quality was made. All cuttings had been rooted for at least 4 weeks or more. The rooting percentages are listed in Table 5. In most instances, the rooting percentages of each kind of plant in both media were comparable. The most substantial differences in rooting were amongst kinds that we have found to be sensitive to excessive moisture, e.g., *Rhamnus frangula* 'Asplenifolia' and *R. frangula* 'Columnaris'. For *R. frangula* 'Asplenifolia' and *R. frangula* 'Columnaris' an 89 and 83% rooting was obtained in the peat-expanded shale medium compared to 74 and 11% rooting, respectively, in the peat-perlite medium. The biggest difference between the two media was in root development after propagation. In all cases, the quality of the root systems in the peat-expanded shale medium was better than in the peat-perlite medium.

Table 5. Effects of propagation media on rooting of selected kinds of woody ornamentals.

	Percent rooting[1]	
Species	Peat: expanded shale (1:1, V/V)	Peat: perlite (1:1. V/V)
Cornus sericea f. bailey	100	89
C. sericea 'Flaviramea'	100	82
Cotoneaster apiculata	77	84
C. horizontalis	78	65
Forsythia × intermedia 'Arnold Dwarf'	86	91
Hypericum kalmianum	71	75
Rhamnus frangula 'Asplenifolia'	89	74
R. frangula columnaris	83	11
Ribes alpinum	78	73
Viburnum × burkwoodii 'Chenault'	78	73
V. × pragense	71	67
Weigela florida 'Java Red'	83	92

[1]Rooting percents are average of between 100 to 800 cuttings for each kind of plant in each medium.

We are pleased with the peat-expanded shale medium and are going to expand our tests next year to include additional kinds of plants. It appears that some plants still root better in the peat-perlite medium but subsequent root growth is still superior on those plants rooted in the peat-expanded shale medium. Another benefit in using the expanded shale product is its cost and handling features. Based on 1985 prices, we are saving about $11.00 per cubic yard of raw material purchased. In addition, we do not have the dust problem in handling the product as we do with perlite and we do not need special storage facilities. The expanded shale product is brought in by tractor-trailer and stored outside in our media mixing area until needed.

In summary, development of a soilless medium necessitates the understanding of media properties and your crop needs. Each grower will have access to potential media ingredients that warrant consideration for use based on specific savings, availability, and specific characteristics they afford a growing medium. For our production system(s), the expanded shale product shows considerable promise.

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ROOTING MEDIA USED AT APPALACHIAN NURSERIES

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At Appalachian Nurseries, we produce a wide range of hardy ornamentals for sale as potted liners. At last count, our propagation schedule included 52 genera with 217 species and named cultivars. Because of this, we use four different media