SUBSTRATE AND VOLUME — A BRIEF REVIEW

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People seldom pay much attention to the effect of substrate *volume* on growth. Most of the applied research is carried out under conditions closely approximating commercial practice. If poinsettias are commonly grown in 6-inch pots, then research is carried out in 6-inch pots. If bedding plants are sold in market paks, then research is carried out in market paks. Nothing wrong with this. Even though most experienced growers are aware of problems with small containers and large plants, both growers and researchers seldom pay much attention to the fact that *volume* has a rather important influence on growth. Fertilizer recommendations, water requirements, etc., are often ignored when tailoring requirements to *volume*. This situation is changed somewhat with the recent introduction of limited volumes such as cubed rockwool for cut flower production. This is a radical change from the relatively large volume of an 8-inch deep bed to the much drastically reduced size of a 3-inch, non-wettable, rockwool cube, or peat-bag, etc. The probable results have been observed when comparing growth of cut flowers or vegetables in the ground versus isolated benches.

Of course, one of the problems is confounding an experiment if volume is changed by changing the depth of the substrate. That is, as shown by Hanan and Langhans in 1964, water retention of shallow, freely draining soil layers can change radically when depth is changed. This might not be so important if it were not for the great interest shown in utilizing small root volumes of various materials for economic production. It has been shown that some of the new inert substrates have considerable advantages in terms of disease control, better nutrition, and often higher yields and faster growth. Unfortunately, most of these new materials are expensive; therefore, the desire to use as little as possible. However, there has not been one publication in the American literature, to my knowledge, that deals with nutrition and water requirements as a function of the volume in which roots of the crop can grow. Our own experience has shown that rose production in cubed, non-wettable rockwool is markedly reduced compared to an 8-inch depth of loose wettable rockwool. Even if watering frequencies are nearly doubled for the shallow (3×9×39-inch) blocks, yield of 'Samantha' will still be less than for a full bench of rockwool (Hanan, 1987; Hanan, unpublished data, 1987). Complicating the whole situation is the addition of non-wetting agents to shallow media to reduce water retention (Wellman and Verwer, 1983). Experience with loose, wettable rockwool in standard benches (Lee et al, 1986) indicates good results for cut flower production. But the same material in shallow pots may lead to difficulty (Lee et al, 1987). Recent observations suggest problems of water supply when a non-wettable material is 6 to 8-inches deep. The material will not retain sufficient water and, crazily, we have been using a wetting agent to increase water retention where the loose rockwool is 6 to 8-inches deep.

Floriculturists have left most of this particular area to agronomists dealing with application of greenhouse experiments to field use. Although a lot of cut flowers are produced in the ground, you will not find one recommendation that deals with the subject of volume in benches versus ground versus small-volumed root substrates. There have been a number of investigations by such agronomists as Armiger et al (1958), Cook and Millar (1946), Stevenson (1967), and Baker and Woodruff (1963). Unfortunately, few, if any, of their test plants were ornamentals, nor were the substrates of the type which we normally deal with in greenhouse culture. Not often were these authors fully cognizant of the relationships between soil depth and water behavior of freely draining, shallow layers (Hanan and Langhans, 1964; Hanan et al, 1978). Despite these problems, the main thrust of all the published research shows that, as volume is decreased, the amount of fertilizer and water required to maintain a commensurate response to that in the open field must be increased.

For example, one of the best studies, conducted by Stevenson, showed that top growth of clover and wheat steadily increased with increasing soil volume, with sunflowers approaching a direct proportionality between growth and soil volume. That is, if soil volume doubled, so did growth. Wheat, however, showed a decreased root-to-shoot ratio with increasing soil volume, indicating, according to Stevenson, that the wheat plant can produce increased top growth without a corresponding increase in root development if the roots have sufficient volume. There was no influence of the watering schedule on top growth, root growth, or the root-to-shoot ratio. Neither was there an interaction between watering schedule and soil volume. Roots growing in small volumes have less water available at relatively low soil water suctions (20 db) than those growing in larger volumes. Twenty decibars is often the recommendation for watering in greenhouse soil mixtures when using a tensiometer to indicate dryness. Roots growing in 244 cubic inches of soil had as much water available after 9 hours of drying as those in 61 cubic inches immediately after irrigation. Water supply will also be influenced by the hydraulic conductivity of the substrate. That is, the ability of water to move from soil to the root in response to the suction force exerted by the root system. Since this conductivity in most greenhouse inert media — and many greenhouse soil mixtures — may drop to zero immediately upon draining after irrigation, the relationships between volume, depth, and water availability can be highly critical.

Baker and Woodruff (1963) also showed that, as soil volume decreased, the fertilization rate had to be increased to obtain comparable results. Corn, grown in pot culture, required 20 times the amount of phosphorous usually applied under field conditions. As soil volume increased, phosphorous applications could be decreased. Cook and Millar's work (1946) showed similar requirements for nitrogen and potassium. In fact, if the usual application rates on a per acre basis employed by farmers are compared with the published recommendations in floriculture (Hanan et al, 1978), one finds recommendations to be an order of magnitude higher for greenhouses.

With the exception of Stevenson, few attempts have been made to relate experience with theory, or to arrive at gen-

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eral principles which would enhance the reliability of research recommendations. Nowhere in present notes and articles are there fertilizer or watering recommendations based upon volume in which plants are grown for greenhouse production. In fact, present recommendations for intensive greenhouse production seldom make mention of such factors as raw water quality, climatic region, depth, irrigation system — not to mention volume. As pressure increases to maximize yields in a competitive market, growers are likely to make some rather expensive, unplanned research projects on their own.

Editor's Note: *An article by Ruff et al. on the effect of restricted root zone volume on tomato growth was recently published in the Journal of the American Society for Horticultural Science (112(5):763-769). The results essentially confirm the conclusions derived from older literature in agronomy cited above. Again, unfortunately, the authors pay no attention to effects of depth on available water, or to the fact that restricted volumes will increase fertilizer requirements. On the other hand, as indicated, the amount of water, or frequency of irrigation, may have little effect on production.*

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INTERNATIONAL PRODUCTION OF CARNATIONS IN 1986

Hoogendoorn, C.

Coop. Ver., Vernigde Bloemenvellingen Aalsmeer

Third International Symposium on carnations, Noordwijkerhout, The Netherlands:

A series of tables, giving carnation statistics compiled by the Aalsmeer Cooperative and presented at the Symposium.

Imports of carnations into the Netherlands (1986):

Country	Millions pieces	Percent
Israel	157	48
Spain	101	31
Columbia	19	6
Kenya	11	4
West Germany	27	8
Others	13	4

Consumption per capita in 1983 (percent):

Country	Rose	Carnation	Chrysanthemum	Total pieces cut flowers
Italy	7	57	9	74
France	24	28	8	25
Switzerland	28	26	6	50
West Germany	21	18	11	66
Netherlands	23	17	16	155
Great Britain	6	11	8	36