allowed to settle before usage. The final grade for this mixture is level with the top of the wooden forms.

Cuttings are then stuck into these prepared areas. We have been able to stick approximately 4500 to 5000 cuttings per wood-form unit. This allows each 6- × 108 ft. bench to contain 67,500 to 75,000 cuttings in an area containing 648 ft^2. We can, therefore, propagate approximately 110 cuttings per ft^2. Using this method of propagation, we can produce very large numbers of rooted liners in a limited space.

Cuttings taken for rooting in these bench areas vary in size from 2- to 6 in. in length. Cuttings such as *Ilex vomitoria* 'Nana' are the shortest in length, while cuttings such as oleander are longer. Most plant material is placed into the benches without the addition of hormone. Hormone compounds are used on plant material that may show accelerated root formation when treated. Most material will root in an acceptable length of time without hormone addition. This rooting is enhanced by the added heat supplied by the sawdust under the rooting bed. Bottom heat in propagation areas has always seemed to enhance the rooting of cuttings.

IMPROVING UNIFORMITY IN CONTAINER NURSERY STOCK

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Abstract. Poor uniformity in container-grown nursery stock increases production and labor costs and decreases effective space utilization and customer satisfaction. Ten major factors that affect crop uniformity are discussed and suggestions are made for improvement.

INTRODUCTION

In most container nurseries poor crop uniformity is a subtle but major factor affecting production costs and customer satisfaction (5). Studies suggest that production costs in a container nursery should be assigned on a square foot of production area per month basis (3,7). With this approach some nurserymen estimate costs based on the period from planting time until sale of the first portion of that crop. However, in many cases the time between the sale of the first portion of the crop and the last may be from a month to a year or more. A more realistic procedure would be based on the time from planting until the last plants from that crop are sold and the space is again available for another crop. The difference in production costs between the first and last sale dates represents a good estimate of the additional cost as the result of poor crop uniformity.

DISCUSSION

Consider the following four factors: 1) A poor plant costs the same to produce as a good one. 2) Poor plants interfere with finding the good ones. 3) Good plants could have been grown in the space of the poor ones. 4) If the poor ones are sold, customers associate a poor plant with your nursery, regardless of the sale price.

There are at least 10 major factors involved in increasing or decreasing crop uniformity. In some cases, these factors are probably additive while others are independent. For example, consider a plant in a container that receives a lower level of fertilizer due to poor mixing of the growth medium, *and* is placed in a position of excessive irrigation water, *and* on the southwest side of a block of plants. It will grow poorly because of excessive leaching of the limited fertilizer. The situation is further complicated by limited root growth due to the excessive termperature. On the other hand, slight differences in container sizes or planting dates within a block of plants are more or less independent of other factors that affect crop uniformity.

The following discussion is based on numerous experiments, experiences, observations, and findings of others:

1. **Parent Plant Selection and Condition.** Always take cuttings from the *best* plants possible. One of the most common errors is in the selection of the parent plants (2,12). If the existing crop is used as the parent stock for cuttings, use the best plants rather than the poorest or last plants available. The argument is sometimes made that it is not practical to take cuttings from the best or first plants to reach marketable size. However, with imagination and planning this can be done and in a profitable manner. For example, take cuttings for the next crop from the first plants to reach marketable size in a particular size container, then shift those plants into the next larger size container, allow one more flush of growth to cover the pruning scars and sell them at a premium price.

A second alternative would be to shift the first plants to reach marketable size into larger containers before the cuttings are taken in order to provide more cuttings or to improve the condition of the cuttings, depending on the species. Never use the end of a crop for stock plants. Think positive and plan ahead.

2. **Selection of Cuttings from the Parent.** Always take the most uniform cuttings possible (6,12). Differences in stem diameter, stem length, number of leaves or buds on a cutting and the presence or absence of flower buds are obvious differences. An important factor often overlooked, however, is the position of the cutting on the plant. With many species plants grown from cuttings from lower side branches grow with a different form than plants from cuttings from the most upright branches.

A plant propagator striving for maximum crop uniformity should be ruthless in selecting cuttings. Establish a narrow tolerance for consistency and reject all others. Remember, it is much more economical to cull a cutting than the resulting inferior plant somewhere later during the production cycle.

3. **Mist Coverage, Water, and Drainage.** Always strive for the most uniform mist coverage *and* the minimum amount of mist that will allow the cuttings to root under your conditions. Most mist systems use some type of circular mist nozzle. In general, more mist nozzles closer together provide a more uniform mist coverage over a bed or bench area. Try placing a series of small containers in several spacings beneath your mist lines. After two or three days, measure or weigh the difference in water among the containers. Perhaps you need to add an additional nozzle in any dry spots.

All containers create a perched water table at the base (9). This means there are saturated conditions in the bottom ¼ to ½ of a shallow tray, bed, or small container. When overwatering occurs either due to excess length of misting or due to position beneath the mist system, air space in the rooting medium is reduced and the rate and uniformity of root development on the cuttings is decreased.

Excess misting, either due to position in the bed or length of misting time, also increases the leaching of metabolites and nutrients from the leaves (10,12). Such leaching increases the variation in growth and quality in an otherwise uniform group of cuttings.

4. **Medium Uniformity.** Always mix the components of the rooting medium uniformly (1). Poor mixing is more easily detected when fertilizers, such as Osmocote 18-6-12, are added (4). As noted under 3 above, the excess water held by the perched water table in all containers is more dramatic in shallow containers or flats. When the rooting medium is not uniformly mixed and some containers receive a slightly different mix, the water retention and aeration of the mix also varies.

Cuttings that root quickly will be much less subject to stress than those that root slowly (8). Plants will be stunted if part or all of their roots are suffocated shortly after a cutting begins to root. This may be due to excess water holding capacity of the mix in the given depth of container or overwatering due to length of misting time.

A substantial portion of the variation in crop uniformity can be eliminated by careful attention to selection of stock plants and cuttings and improving the rooting environment. Above all, be ruthless in grading or selecting rooted cuttings for growing-on; unless the cutting meets strict standards, throw it away.

5. **Container Size.** Always keep containers of the same size together. Also, group species depending on water requirements. For example, when newly-planted, species with different water requirements can be grown together with little consequence. However, as they get larger, if the water is controlled to meet the needs of the plant with the greatest water requirement, the others will be overwatered.

A similar problem occurs when containers of different size are placed under the same watering system. The shallower the container, the more water will be retained relative to the volume of that container. Proper watering is related to size of container, needs and growth stage of the species, capacity of the growth medium to hold water, and time of year. These are important yet very difficult aspects of plant growth to measure, evaluate, or teach.

6. **Water Quantity and Quality.** Always design the most uniform irrigation system possible. Uneven watering is a subtle factor with a major effect on crop uniformity that generally goes unnoticed.

Few irrigation systems have less than a 30% variation in water applied within a given production bed (12). Consequently, if the area that received the greatest quantity of water is monitored, the remainder is under-watered. On the other hand, if the low water area is monitored, the high water area is over-watered. In most cases plant wilting in the low water areas is noticed and water applied. This means more leaching in the high water areas *and* more rapid accumulation of calcium from the irrigation water in the growth medium. Calcium accumulation from the irrigation system is a slow and subtle factor adding to the variation in crop quality. As calcium accumulates, magnesium is displaced and leaches from the container. The increasing calcium restricts the availability and absorption of iron, manganese, and the other micronutrients which, in turn, restricts plant growth and quality. With marginal quality water this shift is more rapid than with good quality water (12).

7. **Mixing.** Always mix components of the growth medium thoroughly and uniformly. Thorough and uniform mixing of components requires considerable precision. A front-end loader can never do a satisfactory job of mixing and should not be used.

There are 3 important factors to remember when using either a paddle- or cement-type mixer: a) do not overfill; b) do not overmix; c) if sand is part of the mix, add it last along with a small amount of water. Three to four minutes is about right for most mixers.

A cement-type mixer may mix 7.5 $yds.^3$ of sand, gravel and cement. However, because they are much less dense, it will not thoroughly mix 7.5 $yds.^3$ of the materials used in container growth media. Perhaps the best guide is to add about 7.0 $yds.^3$ of gross materials, which will shrink 10 to 15% to give about 6.0 $yds.^3$ of actual growth medium.

If a mixer is run too long, especially when sand is present, the dense abrasive sand will pulverize the smaller organic particles and reduce the aeration of the resulting growth medium. A common error is to think that a long mixing time is better. Because of the density of sand, mixing too long can cause a segregation of the different materials and can result in a *poorer* mix. The best everyday analogy is the shaking of popcorn to get the lighter kernels on top and the "old maids" to the bottom.

A useful addition to a paddle-type mixer is a motor-reversing switch. An effective mixing sequence would be: a) add the organic or lightweight components with the mixer off; b) add the nutrient elements (micronutrients, dolomite, lime, etc.); c) turn on the mixer; d) add the sand or any other dense material; e) reverse the mixer briefly; f) return the mixer to normal, then dump. Remember, that unless mixing is thorough and uniform, some containers will receive too few nutrients while others receive too much; the smaller the container the more critical this becomes.

8. **Herbicide Distribution.** Always use every precaution to insure the most uniform distribution of herbicides. Preemergence herbicides, especially on container growth media, tread a fine line between killing or preventing the germination of seed of weed plants, while not injuring the crop plant. The safe yet effective rate of application of most herbicides is very precise. If the rate is too low, weed control is poor and weed competition can stunt crop growth. On the other hand, if the

rate is too high, the crop may be stunted. In either case crop uniformity is decreased.

9. **Seedling Variation.** Be ruthless when selecting seedlings for growing-on. Inherent genetic variation is a problem with most seed-grown woody plants. However, some kinds of plants are much more variable than others (11). For example, seedlings of river birch are very uniform but seedlings of most oaks and other wind-pollinated trees are quite variable.

10. **Other Factors.** Diseases associated with uneven watering, mixing, or drainage may add substantially to the unevenness of a crop.

If the bed surface around the base of each container is not capable of draining away excess water, crop uniformity will be decreased.

In summer the outside row of a block or bed of plants exposed to the afternoon sun will be much hotter than containers partially or completely shaded by foliage or other containers. In winter, plants on the outside rows, especially on the windward side, are more likely to suffer cold injury than plants within a block or bed.

Foliar insects and diseases may reduce crop uniformity in severe cases.

CONCLUSIONS

Variation in plant size and quality is a major factor limiting further mechanization, as well as improved space and labor efficiency in the container nursery industry. The ten items mentioned here may seem like minor factors influencing crop uniformity; however, collectively they can alter the time from planting to sale by many months. The additional attention and effort required to produce a uniform crop will pay big dividends in the long run. Consider the advantage when 500 plants of a species and cultivar are sold — and they are the first 500 plants on the end of a bed:

a) There would be no culls to congregate or shift to another area.

b) Plants ready to be shifted into a larger container could be easily transferred into this area or a new crop begun.

c) The distance traveled by employees and various vehicles would be dramatically reduced.

d) Perhaps best of all, the customer would be satisfied because all of the plants received were *uniform*.

Why should not a customer expect all plants to be like the best ones in the order? The nursery industry should strive for a consistent top quality product.

LITERATURE CITED

1. Brown E. F. and F. A. Pokorny. 1982. Physical and chemical properties of media composed of milled pine bark and sand. *Jour. Amer. Soc. Hort. Sci.* 100:119-121.
2. Coorts, C. D. 1969. The effect of minor element deficiency on rooting of woody ornamentals. *The Plant Propagator.* 15(3): 15-16.
3. Gunter, D. L. and C. N. Smith. 1976. Trends in Florida wholesale nursery sales and costs. *SNA Nursery Research Conf. Proc.* 2:71-72.
4. Henderson, Susan E. and Carl E. Whitcomb. 1980. The effect of rate and time of application of three micronutrient sources on production of *Juniperus procumbens* and *Ilex crenata* 'Hetzii'. *Okla. Agri. Exp. Sta. Rept.* P-103:55-56.
5. Masset, J. 1967. Quality in container nursery stock. *Proc. Inter. Plant Prop. Soc.* 17:75-78.
6. Roberts, A. N. 1969. Timing in cutting propagation as related to development physiology. *Proc. Inter. Plant Prop. Soc.* 19:77-82.
7. Strain, Robert, 1983. Florida container nursery business analysis. *SNA. Nursery Research Conf. Proc.* 28:185-190.
8. Ward, J. D. and Carl E. Whitcomb, 1979. Nutrition of Japanese holly during propagation and production. *Jour. Amer. Soc. Hort. Sci.* 104:523-526.
9. Whitcomb, Carl E. 1975. Plants, pots and drainage. *Hort. Horizons* 9:12-13.
10. Whitcomb, Carl E. 1978. Propagating woody plants from cuttings. *Okla. Agri. Exp. Sta. Tech. Bull.* 733.
11. Whitcomb, Carl E. 1981. Growing tree seedlings in containers. Okla. *Agri. Exp. Sta. Bull.* 755.
12. Whitcomb, Carl E. 1984. Plant Production in Containers. Lacebark Publications, Stillwater Ok. 630 pp.

QUESTION BOX

The 1984 Southern Region Question Box was moderated by Lin Taber, Glen Saint Mary, Florida.

LARRY EDWARDS: I would like more information on crop oil and surfactants. Do these materials have an effect on the chemical with which they are being used?

BRYSON JAMES: They are similar to dormant spray oils and, in general, are nonphytotoxic. They will mix with water. Vegetable oils have been tried, but crop oils are preferred. Ordinary household detergents usually do not interfere with chemical activity if they are nontoxic. Those with high phosphate content should not be used; pH of the solution makes a difference. A spreader-sticker should also be used with most tank mixes. These materials actually have a sticking effect as well as just making water wetter.

TED RICHARDSON: I have found that, in contrast to earli-