decline. It is our recommendation that if a liquid feed system is used, either the grower or the retailer supplement with some other fertilizer. The application of supplemental fertilizer should be done either immediately, if the plants are to be held for several months prior to sale, or after one to two months, if plants have not yet sold. Also, with slow-release-produced plants, growers and retailers should be sure that the slow-release fertilizer has not been completely depleted, and if it has, or is near the end of its release period, supplemental fertilizer should also be applied.

Fertilization information, coupled with other information such as how to water the different types of media used in container production, and what pest problems the grower has been treating, will be of great benefit to the retailer. The grower will benefit by maintaining greater retailer loyalty and by having a superior quality plant on the market.

INFLUENCE OF NUTRITION AND CARBOHYDRATES ON ROOTING OF CUTTINGS

FRED T. DAVIES, JR.

Department of Horticultural Sciences
Texas A&M University
College Station, Texas 77843

It has been difficult to correlate nutrition and carbohydrates to the rooting of cuttings. However, nutrition and carbohydrate status certainly do play an important role in the rooting process.

Carbohydrate pools. There are three carbohydrate pools or sources in the plant system (14). These three pools consist of: 1. free reducing sugars (soluble carbohydrates such as glucose, fructose, sucrose), 2. storage carbohydrates (starches, insoluble carbohydrates), and 3. cell wall polysaccharides. Reducing sugars and storage carbohydrates are the most important for the rooting process.

Carbohydrates are used as building blocks for complex macromolecules in chemical pathways, and also serve as building blocks for structural elements. Keep in mind that in root initiation and development new cell walls are being formed from macromolecules largely composed of carbohydrates.

Carbohydrates are also energy sources. Primary requirements for rooting are: 1. parenchyma cells with the genetic capability to dedifferentiate into root primordia; 2. presence of auxins plus rooting cofactors such as phenolics and essential enzyme systems;

and 3. a substrate energy source of carbohydrates. Essentially carbohydrates are what fuel the engine of rooting.

Nitrogen. Nitrogen is an important component of nucleic acids, DNA, and RNA, which are critical to mitosis and cell division that must occur if adventitious roots are to form. Nitrogen also is a structural component of amino acids that combine to form proteins. Proteins form enzymes that help drive chemical reactions. Thousands of chemical reactions go on at the base of a cutting in the formation of roots.

Competing sinks with rooting. Carbohydrates and nutrition are closely related to rooting when the competition for nutrients, metabolites, carbohydrates and phytohormones occurs among different growth areas of a plant. These other growth areas are "competing sinks" with rooting, which is analogous to the kitchen sink drain through which everything passes when the plug is pulled. In essence, a competing sink is a meristematic region where growth of a flower bud (reproductive primordia) or vigorous vegetative growth (vegetative bud or rapid shoot elongation) competes with the ability of adventitious roots to be initiated and developed at the cutting base.

It is a good practice to pinch flower buds from cuttings to remove this competing sink with rooting. Likewise rapid vegetative growth of axillary buds of leafless hardwood cutting can be a drain on the plant reserves and not only lead to reduced rooting but also to death of the cutting. (8).

Carbohydrate/Nitrogen (C/N) ratios. The importance of carbohydrate/nitrogen levels on flowering, vegetative growth, and rooting has been known since the research of Kraus and Kraybill (2). A high carbohydrate:high nitrogen level of stock plants results in more vigorous nonreproductive vegetative growth with green foliage. This favors rooting of cuttings under intermittent mist. A high carbohydrate:low-to-moderate nitrogen ration of stock plants favors rooting of dormant, leafless hardwood cuttings. Without leaves photosynthesis can not occur. Consequently the cutting must rely on stored carbohydrate reserves for rooting.

A problem in C/N ratios is determining exactly what a high or low carbohydrate/nitrogen level is. This depends upon the plant species, seasonal timing of the year, and type of cutting. Herbaceous cuttings have nitrogen levels of 3 to 5 percent N on a dry weight basis, while woody cuttings have 2 to 2.5 percent N.

One of the few studies to show a correlation with C/N ratios and rooting was with *Rosa multiflora* 'Brooks 56' understock. Production of field roses is a two-year cycle in east Texas that begins with the collection and sticking of dormant hardwood cuttings in late fall. The cuttings are rooted in field beds without irrigation and later T-budded in the following spring (4). During periods of high rooting, the C/N ratio of stock plant cuttings are high, and conversely during low rooting C/N levels decrease (8). Both starch and total carbohydrates contribute to the carbohydrate component of the C/N ratio, but there was no correlation between soluble carbohydrates (glucose, fructose, sucrose) and the rooting of *Rosa multiflora*. Nitrogen was negatively correlated to rooting; that is, high nitrogen depressed rooting.

Manipulation of C/N ratio. There are a number of ways to manipulate the C/N ratio of stock plants from which cuttings are taken. Nitrogen can be manipulated through fertility practices. Fertility of stock plants prior to harvesting cuttings can be reduced.

The carbohydrate component can be altered through light manipulation. Light can be increased by high-pressure sodium vapor lamps, or reduced by the use of shade cloth or saran placed over the stock plants. With selected *Rhododendron* species, growing stock plants under shade suppressed the competing sink of flowering and enhanced rooting of cuttings (10).

Etiolation is an extreme case of C/N manipulation. Changes in morphology and pigmentation occur and rooting success is enhanced. Etiolation and blanching of stock plants can be done under 95 percent shade (11).

The location of a propagule on a stock plant can influence C/N status. Terminal cuttings tend to have greater vegetative growth, which uses up more carbohydrate reserves. Nitrogen levels are higher so that they have a lower C/N ratio when compared to basal cuttings. Spacing stock plants close together reduces vegetative growth and allows accumulation of higher carbohydrate reserves in potential propagules. Pruning practices that reduce reproductive growth divert carbohydrate reserves for potential root formation. Girdling of stock plants prior to taking cuttings has been an effective method to allow carbohydrate accumulation and subsequent enhancement of rooting.

Nutrition. Few studies have approached the effect of nutrition on the various developmental stages of rooting: dedifferentiation, root initial formation, primordia development and elongation. It is quite difficult to conduct these type of developmental rooting studies.

Nutritional analysis has normally been related to the whole cutting tissue or the base of the cutting. Unfortunately this does not tell us what is happening with the nutritional levels of those few cells that are involved in dedifferentiation. Sampling large tissue areas may mask critical nutritional changes going on in those cells that are crucial to the rooting process.

Zinc is an example of how nutrients are directly involved in rooting. Zinc is a microelement and cofactor that helps trigger enzyme systems to convert tryptophan, the immediate precursor of auxin, to IAA.

Boron can enhance adventitious root formation by mobilizing citric and isocitric acids necessary to rooting and by increasing the uptake/absorption of auxin into the cutting. Boron can also decrease rooting by enhancing IAA oxidase activity, which metabolizes and breaks down endogenous auxin.

Manganese is another microelement that activates IAA oxidase to the detriment of endogenous auxin. In one of the few studies where there was a direct relationship between nutrient levels and rooting, easy-to-root clones of avocado had low Mn levels whereas difficult-to-root avocado clones had high Mn levels (12).

Most containerized nursery growers do not have the luxury of stock plant blocks, which means that cuttings are harvested from containerized plants. These may be under optimal nutritional conditions for production but not ideal conditions for rooting. It would be best in maintaining the momentum of the cutting that moderate nitrogen levels be maintained rather than high production levels. It is equally important that nutrient deficiency be avoided since the only nutrients a cutting has to rely on are endogenous levels at the time when cuttings are harvested from stock plants. A nutritionally deficient cutting creates cultural problems that are compounded throughout the whole production system. The result is an inferior product and increased cost due to a longer production time.

Leaching of nutrients with intermittent mist. Intermittent mist can severely leach nutrients from cutting leaves. Nitrogen and manganese are readily leached; calcium, magnesium, sulfur and potassium are moderately leached; and iron, zinc and phosphorus are leached with difficulty (5). When leafy cuttings are detached from the stock plant and placed under mist, the only nutrients available to the cutting will be its internal supply until after it has initiated roots. This means that with the rapid leaching that occurs under mist, a cutting can "run empty" very quickly. A difficult-to-root cutting usually takes much longer to form roots, and it is not surprising that nutritional deficiencies and disease problems compound the rooting problem.

Foliar deficiencies of cuttings can become quite apparent due to leaching, depending on the cuticle and wax thickness of the species and the growth stage of the cutting material. Leafy, semi-hardwood cuttings are more susceptible to leaching than softwood or herbaceous cuttings. A greater portion of nutrients is in an exchangeable form than in young growing tissues that more quickly metabolize nutrients within cells and cell walls (1). Foliar deficiencies can also occur with the redistribution or mobilization of nutrients within the cutting.

Reducing nutritional problems caused by mist. There are ways to improve nutrition of cutting after roots are formed (15). One way is by reincorporating a slow-release fertilizer such as Osmocote

18-6-12 at 2 to 6 lbs. per cu. yd. in the propagation medium. Some growers use as high as 8 lbs. but each producer needs to try small tests to determine what works best with his particular propagation system and species. Osmocote at ¼ to ½ ounce per square foot has also been top dressed on propagation media (7).

Dilute liquid fertilizer can also be applied after cuttings have formed roots. Using nutrient mist has not been an effective method since algae form on the medium and create aeration, drainage, and subsequent disease problems for cuttings.

There is little evidence to indicate that adding nutrients aids root initiation. Instead fertilization after root initiation can improve cutting root development and help speed up the production of rooted liners. The response of cuttings to fertilization is species specific. Cuttings of *Cotoneaster* spp. (3), *Ilex crenata* (15), *Juniperus conferta*, and *Ligustrum japonicum* (9) had increased root development, whereas *Syringa villosa* and *Thuja occidentalis* (3) showed no response. Some species are difficult to overwinter as rooted cuttings. *Acer palmatum* and *Cornus florida* cuttings may be adversely affected if nitrogen fertilizer is added to rooted cuttings in the fall prior to overwintering (6). On the other hand, growth flushes of rooted cuttings in late summer-early fall or with artificial long-day conditions may restore carbohydrate reserves important for good winter survival of cuttings taken late in the season (13).

Another method to avoid nutrient leaching problems is to use propagation systems other than conventional open mist. A closed mist system encased in a frame supporting polyethylene results in higher relative humidity. The actual amount of mist applied and, therefore, leaching can be reduced. Contact polyethylene sheets where semi-hardwood and hardwood cuttings are rooted without mist also avoid nutrient leaching problems. Fog systems with small-sized water droplets ($<50\mu$) use less water and also avoid nutrient leaching.

LITERATURE CITED

1. Blazich, F. A. 1988. Mineral nutrition and adventitious rooting In Davis, T. D., B. E. Haissig, and N Sankhla (eds.) *Adventitious Root Formation in Cuttings* Portland, Oregon:Dioscorides Press, pp 61–69.
2. Cameron, J S. and F. G. Dennis, Jr 1986 The carbohydrate-nitrogen relationship and flowering/fruiting:Kraus and Kraybill revisited. *HortScience* 21.1099–1102
3. Chong, C 1982 Rooting response of cuttings of two cotoneaster species to surface-applied Osmocote slow-release fertilizer. *The Plant Propagator* 28:10–12.
4. Davies, F T. Jr., C. E. Hambrick III, Y. Fann, and H B Pemberton. 1986. Grafting and adventitious root formation of Texas field rose bushes *Acta Hortic* 189 89–100.
5. Good, G L and H. B. Tukey, Jr. 1966 Leaching of metabolites from cuttings propagated under intermittent mist. Proc Amer Soc Hort Sci 89:727–733.

6. Goodman, M. A and D. P. Stimert. 1987 Factors regulating overwinter survival of newly-propagated stem tip cuttings of *Acer palmatum* Thunb. 'Bloodgood' and *Cornus florida* L. var. rubra. *HortScience* 22:1296–1298.

7. Gouin, F. R. 1974. Osmocote in the propagation house. *Proc Inter Plant Prop Soc* 24:337–341.

8. Hambrick, C. E. III. 1985 The correlation of carbohydrate/nitrogen ratios and rooting ability of *Rosa multiflora* stem cuttings. M S. Thesis, Texas A&M University, College Station.

9 Johnson, C R. and D F. Hamilton. 1977 *Jour. Amer Soc Hort Sci* 102:320–322.

10 Johnson, C. R. and A. N. Roberts. 1968. The influence of terminal bud removal at successive stages of shoot development on rooting of *Rhododendron* leaves. *Proc Amer Soc Hort Sci* 93:673–678

11. Maynard, B. K and N L Bassuk 1987. Stock plant etiolation and blanching of woody plants prior to cutting propagation. *Jour Amer Soc Hort Sci* 112:273–276.

12. Reuveni, O. and M. Raviv. 1981 Importance of leaf retention to rooting avocado cuttings. *Jour Amer Soc Hort Sci* 106:127–130.

13. Smally, T. J. and M. A. Dirr. 1988. Effect of night interruption photoperiod treatment on subsequent growth of *Acer rubrum* cuttings. *HortScience* 23:172–174.

14. Struve, D K. 1981. The relationship between carbohydrates, nitrogen, and rooting of stem cuttings. *The Plant Propagator* 27(2):6–7.

15. Wright, R D., J. N Booze-Daniels, and R. E. Lyons. 1984 How long should growers wait to fertilize cuttings that have rooted. *Amer. Nurs* (Feb. 15):57–59.

GROUND BEDS VS. CONTAINERS FOR SEEDS AND CUTTINGS

RANDY DAVIS

Greenleaf Nursery Company
Route 1, Box 163
Park Hill, Oklahoma 74464

Greenleaf Nursery, located in Park Hill, Oklahoma, is a wholesale nursery specializing in production of "Predictable Quality" container-grown ornamentals. Besides ornamental shrubs and trees we also grow annual and perennial color crops for fall and spring.

At Greenleaf we produce about 10 million liners annually. Most are propagated by cuttings, but we also propagate by seeds, grafting, budding and division. Our liners are grown either in ground beds or in containers, depending on the type program we have for production of that crop.

In our production the most economical method of liner production is through the utilization of raised ground beds rather than containers. Cuttings are rooted in ground beds, grown in this method