

Basics of Propagation by Cuttings: Light

Brian K. Maynard

Department of Plant Sciences, University of Rhode Island, Kingston, Rhode Island 02881-0804

INTRODUCTION

No one would deny that the amount or type of light reaching a cutting is important to the success of plant propagation. There is ample evidence that light profoundly affects the formation and growth of roots. Why is it then that the level of light, and the sources of light are mentioned so rarely in reports and studies of propagation methods? In the industry it has become a matter of course to provide 50% shade, or to whitewash the propagation greenhouse. Beyond these measures little attention is given to manipulating the light level around the cutting to increase rooting. Not that it is all that difficult to vary the amount of light a cutting receives. Shading in a variety of forms and densities is available from most grower supply firms. Also, easy-to-use light sensors are available that will measure irradiance in footcandles (FC) for as little as \$50 to \$250. Understandably, however, much of the attention given to light is directed toward its frequent byproduct—heat. Ventilation, mist, fog, and shading all are used to maintain the air temperature in the propagation bench within a reasonable range. In this brief treatment of light and rooting, I will concentrate on several ways by which light interacts with cuttings rooting in the propagation bench.

Light shines in several ways—the strength or level of irradiance, the photoperiod or duration of light exposure on a 24-h time scale, and the spectral quality of light. Each of these factors has been studied on a variety of crops, and each has the potential to affect the initiation and growth of roots on cuttings. The reader who desires a more in-depth discussion of how light affects rooting is directed to several *fine treatments published in recent years* (Davis, 1988; Hartmann et al., 1992; Loach, 1988; Moe and Andersen, 1988).

HOW LIGHT LEVELS AFFECT ROOTING

Adventitious root formation is a metabolic process, and as such requires energy and is responsive to environmental factors such as water (e.g., irrigation) and temperature (e.g., bottom heating). The energy used in rooting comes from respiration, which in turn relies on supplies of carbohydrate (sugars, starch, etc.) stored in the leaves and stems of the cutting. Remember also that the act of taking a cutting severely wounds the plant stem, and so other metabolic processes besides those leading to rooting figure highly in the energy budget of the cutting, for example, the compartmentation of the wound surface by callusing and formation of wound-response chemicals. Cuttings of some species even continue to grow in the propagation bench, also drawing on stored energy reserves. All of these processes together draw from the one or a few available pools of carbohydrate. Each metabolic process, including root initiation and elongation, competes for energy, and likely is regulated by the extent to which it can commandeer this finite supply. Higher intensities of light have been

correlated, in a number of studies, with the production of more roots (Moe and Andersen, 1988). This could be expected if carbohydrate levels were limiting root initiation or the growth of initiated roots. Of course, leafless hardwood cuttings depend entirely upon stored carbohydrates, which may be why winter cuttings of some species, replete with starch and energy stored for spring growth, root better than cuttings taken earlier or later in the year.

Cuttings with leaves intact have the potential advantage of manufacturing new carbohydrates while in the propagation bench. However, their capacity to do so will depend on several factors. One factor common to all leafy cuttings is water stress, a big killer of unrooted cuttings. Cuttings become severely water stressed following harvest from the stock plant, and often remain stressed until new roots form (Grange and Loach, 1983). A consequence of cutting stress is the closure of the stomates, by which further water loss is reduced. Herein lies a problem, however, because while water is being conserved, carbon dioxide, the building block of photosynthesis, is being excluded from the leaf (Davis, 1988). Unable to take up carbon dioxide, the leaves of stressed plants can not photosynthesize very well, and can not benefit from lighting supplied for that purpose. It has been proposed that measures such as overhead mist and fog are beneficial because they reduce cutting stress and permit higher rates of photosynthesis. Rates of photosynthesis typically rebound following the formation of new roots, presumably because water stress in the cutting has been relieved and stomates re-open (Davis, 1988).

Another means of reducing cutting stress is shading. Shading at a level of about 50% is very common in propagation facilities, but the need for shade varies with the crop and time of year. Many propagators focus, understandably, on the foliar heating and water stress that can result from high light levels reaching the propagation bench. This is because, in the short-term, drying of the cutting or burning of the foliage can easily break a production schedule. In his recent treatise on light and rooting, Loach (1988) suggested maintaining lower light levels until roots have formed and then increasing light levels to promote growth of the new root.

Other speakers today have addressed remedies for overheating and water stress. From our perspective, suffice it to say that light and heat are one and the same—energy—differing only in its wavelength. A major influence of light on the leaf is to increase leaf temperature. Heating also is a byproduct of inefficiency in photosynthesis, particularly if the leaf receives more light that it can use—i.e., if photosynthesis is “overdriven.” One of the functions of transpiration—the movement of water through plants—is to cool the leaf. Cooling prevents damage to the leaf and preserves the efficiency of photosynthesis. When heating is too great, as under excessive light levels, the ability of transpiration to cool the leaf may be exceeded—resulting in damage. Simply the fact that cuttings are limited in their ability to cool themselves, by taking up and distributing water, is enough reason to reduce light levels in the propagation facility.

In their popular plant propagation textbook, Hartmann, Kester, and Davies (1992) define an optimal light level for rooting leafy cuttings that falls in the range of 20 to 100 W/m² (~ 200 to 1000 FC; or between ~ 50% and 95% shade on a sunny day). Below 20 W/m², rooting is reduced in a variety of plant species (Loach and Whalley, 1975), probably because photosynthate becomes limiting.

While full sunlight can reach 1000 W/m² (~10,000 fc), it is usually less due to the

angle of the sun, cloud cover, dust/air pollution, etc. (Loach, 1988). The process of photosynthesis in the leaves of many woody plants saturates in the range of 100 to 500 W/m² (~1000 to 5000 fc), or somewhere between 1/10 and 1/2 full sunlight. Photosynthesis in cuttings may saturate at even lower levels because of stomatal closure or a limited “sink” capacity for carbohydrates in the cutting (Loach, 1988). In general, the leaves of herbaceous cuttings can handle higher light levels than those of woody cuttings, because they have a high saturation point for photosynthesis (Larcher, 1980). The compensation point of many plants, i.e., the light level at which the loss of carbohydrates through respiration exceeds the formation of carbohydrates through photosynthesis, lies in the range of 3 to 15 W/m² (~30 to 150 fc).

What these numbers tell us is that recommended light levels will generally exceed the light compensation point of the cutting, even when shading is used. This means that some extra carbohydrates will be manufactured which can go towards supporting root initiation and growth. At 100 W/m², the high end of recommended light levels, photosynthesis may even be running full tilt for certain species.

Our best shot in manipulating light levels to promote rooting may be to strike a balance between having enough light to yield a net gain in the products of photosynthesis, and maintaining an environment that minimizes cutting stress. In all likelihood the practice of shading with 50% saran shade cloth does this, though we remain ignorant of the actual degree to which we are achieving each of these antagonistic objectives. There would be considerable commercial value in research directed towards measuring the balance of carbohydrate production and cutting water stress. However, there are means of promoting photosynthesis without further stressing the cutting. For example, carbon dioxide enrichment of the atmosphere surrounding the cutting could be used to increase the efficiency of photosynthesis, thereby increasing carbohydrate production and rooting (Moe and Andersen, 1988).

HOW PHOTOPERIOD AFFECTS ROOTING

The length of the day, or more accurately, the length of the night, has long been known to influence plant growth. Photoperiod is routinely manipulated to control the growth and flowering of greenhouse crops, and has been studied in various woody plant propagation systems.

In many plants longer photoperiods promote bud break and shoot growth, and the resulting succulent growth oftentimes roots more easily. Short days (long nights), conversely, reduce shoot growth and stimulate bud set. Woody plants in this semi-hardwood or hardwood stage of growth often are more difficult to root. Longer photoperiods also produce higher levels of carbohydrates and auxins in cuttings—resulting perhaps from longer periods of photosynthesis and more active shoot growth. Some propagators have argued that promoting bud break or shoot growth on cuttings in the propagation bench may reduce rooting by using up stored energy. Indeed, Whitcomb has proposed that shoot growth is favored over root growth in plants having limited supplies of carbohydrates (Whitcomb, 1984). One should be aware also of the antagonism between flowering and rooting, and avoid rooting cuttings under photoperiods that promote flowering or dormancy (Moe and Andersen, 1988).

However, promoting the active growth of rooted cuttings, either in the bench or

soon after rooting, may be critical to the overwinter survival of many species. A flush of growth after rooting improves the overwinter survival of cuttings in several genera, including *Acer*, *Betula*, *Cornus*, *Corylopsis*, *Hamamelis*, *Magnolia*, *Rhododendron*, *Stewartia*, and *Viburnum* (Smalley et al., 1987). A long photoperiod or night break is often the key to stimulating this secondary flush of growth. The caution in using this technique is to ensure the new growth is hardened off before winter weather sets in, if liners are to be overwintered out of doors.

It has been suggested that higher carbohydrate levels in roots and stems are responsible for the increased survival and growth of liners that grow on after rooting. Yet, it simply may be a matter of having enough to make it through the winter and meet the demand for carbohydrates when shoot growth resumes in the spring (Loach and Whalley, 1975). Principles of Accelerated Optimal Growth (AOG), which strive to achieve the most growth in the first year of production, also call for long photoperiods (Hanover, 1976). Some AOG systems even go so far as to use 24-h days to keep plants growing.

HOW LIGHT QUALITY AFFECTS ROOTING

The influence of light quality on rooting has received more attention relative to preconditioning stock plants for good rooting, rather than increasing rooting in the propagation bench. Exposing stock plants to blue light and cuttings to red light have both been shown to improve rooting (Hartmann et al. 1993). Using lighting that gives more red than far-red light appears to increase rooting in many greenhouse crops (Moe and Andersen, 1988). Though it is probable that root initiation, like many other plant growth processes, is regulated somehow by red and far-red light through the phytochrome molecule, this is not an easy area of study, varies among species, and may be limited in commercial application.

THE INHIBITION OF ROOTING BY DIRECT LIGHTING OF THE CUTTING BASE

Considerable evidence exists that light directly inhibits root emergence. The most often cited study is that of Shapiro (1958) who used stem cuttings of Lombardy poplar to show that preexisting root initials would not grow out in the presence of light, and that red light was more inhibitory of root emergence than far red light (an implication of involvement by phytochrome), green or blue light. Indeed it is generally accepted that a role of rooting media is to shield the base of the cutting from light (Hartmann et al., 1992). The direct inhibition of root initiation or elongation is not well understood on the molecular/biochemical level. It has been proposed that light is destroying auxin, changing the ratio of promoting/inhibiting phenolics, activating auxin oxidases or enzymes that conjugate auxin and phenolic compounds, etc. Many biochemical processes kick in when a cutting is separated from its root system. Light also affects numerous events in plant growth and development, from seed germination to flowering. Determining what conditions in the rooting bench are most responsible for the control of root initiation and elongation is beyond our scientific abilities at present. The answer to these questions may lie in the exciting fields of molecular biology and genetic engineering. In the mean time, keep those cuttings cool on top and warm below!

LITERATURE CITED

- Davis, T.D.** 1988. Photosynthesis during adventitious rooting. In: Adventitious root formation in cuttings, T.D. Davis, B.E. Haissig, and N. Sankhla, (eds.). Dioscorides Press, Portland, OR
- Grange, R.I. and K. Loach.** 1983. The water economy of unrooted leafy cuttings. *J. Hort. Sci.* 58:9-17.
- Hanover, J.W.** 1976. Accelerated optimal growth: A new concept in tree production. *Amer. Nurseryman* 144 (10): 12-13, 58, 60, 64-65.
- Hartmann, H.T., D.E. Kester, and F.T. Davies, Jr.** 1992. *Plant Propagation: Principles and Practices*. 5th Edition. Prentice Hall, Englewood Cliffs, New Jersey.
- Larcher, W.** 1980. *Physiological plant ecology*, 2nd ed. Springer-Verlag, New York.
- Loach, K.** 1988. Controlling environmental conditions to improve adventitious rooting. In: Adventitious root formation in cuttings, T.D. Davis, B.E. Haissig, and N. Sankhla, (eds.). Dioscorides Press, Portland, Oregon.
- Loach, K. and D.N. Whalley.** 1975. Use of light, carbon dioxide enrichment and growth regulators in the overwintering of hardy ornamental nursery stock cuttings. *Acta Hort.* 54: 105-115.
- Moe, R. and A.S. Andersen.** 1988. Stock plant environment and subsequent adventitious rooting. In: Adventitious root formation in cuttings, T.D. Davis, B.E. Haissig, and N. Sankhla, (eds.). Dioscorides Press, Portland, Oregon.
- Shapiro, S.** 1958. The role of light in the growth of root primordia in the stem of Lombardy poplar. In: *The physiology of forest trees*, K.V. Thimann, (ed.). Roland Press, New York.
- Smalley, T.J., M.A. Dirr, and G.G. Dull.** 1987. Effect of extended photoperiod on budbreak, overwinter survival, and carbohydrate levels of *Acer rubrum* 'October Glory' rooted cuttings. *J. Amer. Soc. Hort. Sci.* 112:459-463.
- Whitcomb, C.E.** 1984. *Plant production in containers*. Lacebark Publications, Stillwater, Oklahoma.

PETER VERMEULEN: Has any additional work been done on light interruptions of the dark period since the work of Dr. Cathy?

BRIAN MAYNARD: The most recent is by Smalley and Dirr that I am aware of in relationship to restarting growth.