Improving the Postharvest Quality and Rooting of Cuttings©

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The most common postharvest ethylene-related problems include leaf senescence (yellowing) and/or abscission of matured leaves. Successful postharvest shipment of non-rooted vegetative cuttings is dependent on the interaction between endogenous carbohydrate status and ethylene sensitivity. Plant sensitivity to ethylene is dependent on the carbohydrate status of the cutting. Cuttings harvested at the end of the day possess relatively high carbohydrate levels and are less sensitive to ethylene action. In contrast, cuttings harvested early in the morning have low carbohydrate levels and are more sensitive to ethylene in the post-harvest environment. Application of the ethylene-blocker 1-MCP inhibits leaf senescence and abscission regardless of the endogenous carbohydrate status and ethylene production.

Successful rooting of vegetative cuttings is dependent both on preharvest carbohydrate status and current photosynthesis during the course of propagation. When cuttings produced under high light levels at tropical locations are shipped and propagated under lower light during winter months, their net carbon assimilation will be impaired. This is primarily due to the poor photosynthetic performance of the cuttings during propagation because of the improper adaptation of their photosynthetic apparatus. The survival and root formation of those cuttings can be improved by supplemental lighting during propagation.

INTRODUCTION

The commercial production of vegetatively propagated ornamental plants has continued to grow over the past two decades. In the past 10 years, most stock plant production has relocated to tropical climates that allow for lower fuel requirements and higher availability of lower wage labor. For the North American market, cutting production primarily occurs in Mexico, Guatemala, and Costa Rica with production also in Brazil and Colombia. In 2005, more than 860 million nonrooted cuttings were imported into the U.S.A. (Jerardo, 2006). Due to the perishable nature of the product, non-rooted cuttings are transported by airfreight. The process from cutting to delivery to the customer typically requires 2 to 3 days, but temperature control is often lacking along portions of the cold-chain. The targeted temperatures in transit range from 2 to 10 °C, depending on species. Since species are often combined in shipments, 10 °C is the temperature provided to reduce chilling injury of sensitive species. Fluctuations of 10–20 °C are common during individual shipments. As a result, the cuttings are frequently exposed to non-optimal temperatures that have a negative impact on cutting postharvest longevity.

Cutting produced at the tropical locations are adapted to the higher light levels. When those high-light-adapted cuttings are propagated under lower light levels in the greenhouses during winter months, the survival and root formation of the cuttings are affected not only by the unfavorable conditions during shipment but also by insufficient adaptation of the cuttings to the prevailing low-light levels. Cuttings are usually delivered to customers while they still have a desirable appearance; however their performance in propagation is often reduced compared to nonshipped cuttings. Detrimental symptoms often appear during the first week in propagation and the common symptoms include leaf chlorosis, necrosis, and delayed or uneven rooting. These common physiological problems arise from carbohydrate depletion and ethylene sensitivity during shipment and poor photosynthetic performance during propagation. Postharvest quality of the cuttings as affected by the interaction between carbohydrate status and ethylene action and rooting performance of the cutting as affected by current photosynthetic performance will be discussed.

POSTHARVEST QUALITY: CARBOHYDRATES, ETHYLENE, AND INTERACTION

The carbohydrate concentration of cuttings is influenced by the time of day at which the cuttings are harvested (Rapaka et al., 2007a, b). Cuttings have the lowest carbohydrate concentration early in the morning, since they have been respiring throughout the night. In *Portulaca*, the carbohydrate concentration in the leaves and the starch content of the stem increases throughout the day as photosynthesis progresses, while the sugar content of the stem is relatively constant (Rapaka et al., 2007a), thus afternoon-harvested cuttings have higher initial carbohydrate concentrations.

The postharvest ethylene production of cuttings is not influenced by the time of day at which the cuttings are harvested (Rapaka et al., 2007a, b). Ethylene concentrations >0.25 ppm are commonly measured in packages of cuttings after 48 h in postharvest. Packages with ventilation will reduce the concentration inside the package but do not prevent ethylene damage (Kadner et al., 2000). The most common symptoms are leaf chlorosis or leaf abscission. If severe temperature abuse occurs in transit or the shipment is delayed, cuttings may exhibit symptoms when boxes are first opened. More commonly, leaves will turn yellow or abscise during the first 2 to 5 days in propagation. Even if the survival percentage is not reduced, the increased labor required for cleaning the damaged leaves is a problem for propagators.

The postharvest quality of the nonrooted vegetative cuttings is dependent on the interaction between endogenous carbohydrate status and ethylene sensitivity. In *Portulaca* cuttings, ethylene production did not change among cuttings harvested at different times of the day, while ethylene-induced leaf abscission was significantly reduced by afternoon cutting harvest when carbohydrate levels were much higher than during the morning (Rapaka et al., 2007a). Similarly, in *Pelargonium*, exogenous ethylene application only resulted in marginal breakdown in chlorophyll content when carbohydrate status was higher. In contrast, when carbohydrate status was lower, ethylene application resulted in significant chlorophyll breakdown and substantial senescence promoted leaf decay (Rapaka et al., 2008). These results indicate that postharvest ethylene action decreased with the increase in pre-harvest endogenous carbohydrate status.

While the time of harvest is not critical for many species, those species or cultivars that are particularly sensitive to ethylene are the most likely to benefit from afternoon harvesting, e.g., *Portulaca*, *Lantana, Pelargonium, Euphorbia,* etc. Cutting suppliers often try to harvest cuttings early in the day when greenhouse temperatures are coolest. This is obviously a detrimental practice for certain species or cultivars. In such cases, it is better to harvest the cuttings the previous day in the afternoon, then store them at the optimal temperature overnight and ship them the following day. Application of ethylene action blocker 1-MCP inhibits leaf abscission and leaf senescence (Faust and Lewis, 2005; Rapaka et al., 2007b; Rapaka et al., 2008) but can also slightly delay rooting in some species by a day or two. Rescheduling the time of harvest to afternoon along with 1-MCP application is the best way to improve the postharvest quality of ethylene sensitive nonrooted cuttings.

ROOTING PERFORMANCE: INTERPLAY BETWEEN PREHARVEST CARBOHYDRATES AND CURRENT PHOTOSYNTHESIS

Intensive and complex investigation on pelargonium shoot-tip cuttings indicated that cuttings with a higher and steady export capacity of carbohydrates from the source leaves to the region of root regeneration during the early propagation period were repeatedly able to show a higher rooting response (Rapaka et al., 2005). Highly significant correlations were observed between sucrose concentration in the leaves over the first 7 days of propagation and the final root count of the cuttings. The results imply that the basipetal influx of sugars from the source leaves during the early rooting period is a major determinant of the intensity of root formation in leafy stem cuttings (Rapaka et al., 2005). This is because leaf-derived basipetal influx of carbohydrates may facilitate co-transport of other compounds required for root formation (Druege et al., 2004; Rapaka et al., 2005), particularly in relation to the vascular transport of auxins (Baker, 2000). It was also found that the abundance of initial carbohydrate reserves in the stem base at harvest is not the basis criteria for rooting of cuttings. The initial carbohydrate reserves in the stem base might only meet the basic energy requirements for root formation.

Steady and higher supply of carbohydrates from the source leaves to the region of root regeneration depends both on pre-harvest carbohydrate availability and current photosynthesis during the course of propagation (Rapaka et al., 2005). This dependency on current photosynthesis during propagation is particularly important in the case of shipped or even short-term stored cuttings. This is due to the fact that the carbohydrate levels of the cuttings deplete significantly during the shipment procedure. Among the leaf and stem carbohydrates of the cuttings, the carbohydrates levels in the leaves deplete significantly during the shipment procedure. This is because of the high availability of leaf carbohydrates for respiration and other metabolic processes that occur during dark storage, even at low temperatures (Rapaka et al., 2005). Once those stored cuttings are placed on the propagation bench the carbohydrate pools in the leaves need to be refilled before they can start exporting carbon besipetally to the region of root regeneration (Rapaka et al., 2005). Therefore, for successful rooting of stored or shipped cuttings, current photosynthesis during the course of propagation is utmost important.

The current photosynthetic efficiency of the cutting is affected by the change in light levels from the stock plant environment to the propagation environment (Rapaka et al., 2005). When high-light-adapted cuttings produced in the tropical locations are shipped to temperate climates during the winter months and propagated under lower light levels the net carbon assimilation will be impaired (Druege et al., 2004). This is primarily due to the down-regulation of photosynthetic apparatus because of insufficient adaptation to the prevailing lower light levels in temperate regions during winter months. The survival rate and rooting performance of those insufficiently adapted cuttings can be inferior because they depend on the cutting's initial carbohydrate availability (Rapaka et al., 2005). However, in such cases, improvement in survival and rooting can be achieved by providing supplemental lighting during the course of propagation. Maintaining the light levels between 3 to 6 $mol \cdot m^{-2} \cdot day^{-1}$ during propagation would benefit the rooting performance of the cuttings.

CONCLUSIONS

It can be concluded that the postharvest ethylene sensitivity of nonrooted cuttings decreases with the increase in pre-harvest endogenous carbohydrate status and as a result leaf abscission and leaf senescence will decrease. Alternatively, if preharvest carbohydrate levels are low, the cuttings of ethylene-sensitive species are highly susceptible to rapid leaf abscission or degradation of chlorophyll resulting in chlorosis of the older leaves. The quality of ethylene sensitive nonrooted cuttings can be improved by rescheduling the time of harvest and application of 1-MCP. Adventitious root formation in leafy stem cuttings depends both on preharvest carbohydrate status and current photosynthesis during propagation. When high-light-adapted cuttings from tropical locations are propagated under lower light in temperate climates the survival and rooting can be inferior. Supplemental lighting during propagation can significantly promote the rooting.

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