

Cold-Chain Management

Academics share tips on managing and monitoring temperature in the shipping and sticking process.

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TEMPERATURE management is the predominant factor that impacts the post-harvest performance of horticultural crops. Over the past several years, we have been working with cutting suppliers to improve the reliability of delivering unrooted cuttings that perform well in propagation. Inevitably, all roads lead back to temperature management.

Cutting performance relies on strong cold-chain management. The strength of a chain depends on each of the individual links from the time of harvesting the cutting until the cutting is stuck on a propagation bench. This article will discuss why temperature management is so important and will provide guidelines for growers for handling boxes of unrooted cuttings.

Post-Harvest Physiology 101

Temperature is so critically important because it directly affects physiological processes such as respiration and ethylene production. Let's take a moment to review some basic post-harvest physiology principles.

Respiration is the process by which carbohydrates (sugars and starches) are broken down into carbon dioxide. During this process, energy is produced. This energy is used to sustain the basic functions and structure of the plant. Respiration consumes oxygen and produces carbon dioxide, so

the concentration of these gases will change in the environment surrounding plants that are packaged in the post-harvest environment. Specifically, oxygen can drop from the normal 21 percent of the atmosphere down to as low as 0 to 1 percent. Packages normally have to be tightly sealed to create very low oxygen conditions, but if this happens, then anaerobic conditions are created and this will result in very smelly, rotten plant tissues.

Ambient carbon dioxide is ~0.035 percent, but those levels will increase in the post-harvest environment to as high as 20 percent. Plants can be sensitive to 5 to 10 percent carbon dioxide, which will cause the tissues to break down and become water-soaked.

The rate of respiration in plant tissues increases exponentially as temperature increases. In other words, the respiration rate doubles with every 18°F increase in temperature. Thus, if the respiration rate equals one at 40°F, then it equals two at 58°F. It then doubles again to four as the temperature increases to 76°F. Thus, the respiration rate is four times higher at 76°F compared to 40°F.

Ethylene production by plants is also a function of temperature. The wounding process that occurs when a cutting is removed from the stock plant creates a chain reaction of plant biochemistry that results in ethylene gas being produced by the plant tissues. Ethylene is a signal to the plant that a stress has occurred. If the plants are kept at their optimal

Leaf yellowing of zonal geranium can be caused by warm shipping temperatures. Lower leaves turn yellow when they are depleted of carbohydrates and the plants are exposed to ethylene.

post-harvest temperature, very little ethylene is produced; however, after a couple of days in a warm box, one can measure as much as 1 ppm ethylene, which can cause leaf chlorosis and/or rapid leaf abscission.

Performance Following Post-Harvest Stresses

Poor temperature management can cause several different problems. In tightly sealed packages, carbon dioxide toxicity or anaerobic conditions (low oxygen) can cause the collapse of plant tissues, although this is quite rare. More commonly, ethylene-sensitive species will display leaf yellowing or leaf abscission. If the exposure to ethylene is relatively high, these symptoms can be observed while the cuttings are being stuck; however, more commonly the symptoms are not expressed until the cuttings have been on the propagation bench for one to four days.

The effects that high respiration rates in the post-harvest environments have on propagation performance are less obvious. To understand this, we must first remember that when a cutting is harvested and placed in a box, its ability to produce more food (carbohydrates) is zero. Thus, the cutting is now having to live entirely off

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of its carbohydrate reserves. During post-harvest shipping, these food reserves are continually in decline. The warmer the environment, the faster they are in decline.

After two to three days of shipping, the sugar concentrations in the leaves may be negligible. When the cutting is stuck in propagation, the leaves begin to do photosynthesis once again and then start to replenish the depleted



Exposure to warm temperatures during shipping can cause leaf abscission, as seen here in thunbergia.

carbohydrate levels. This must occur before those leaves can start to supply the base of the stem with the energy need to begin root formation. As a result, the more depleted the cutting carbohydrate levels at sticking, the longer it takes for the rooting process to begin. The bottom line is that a cutting that has experienced cooler temperatures during shipping will begin the rooting process sooner and with greater uniformity.

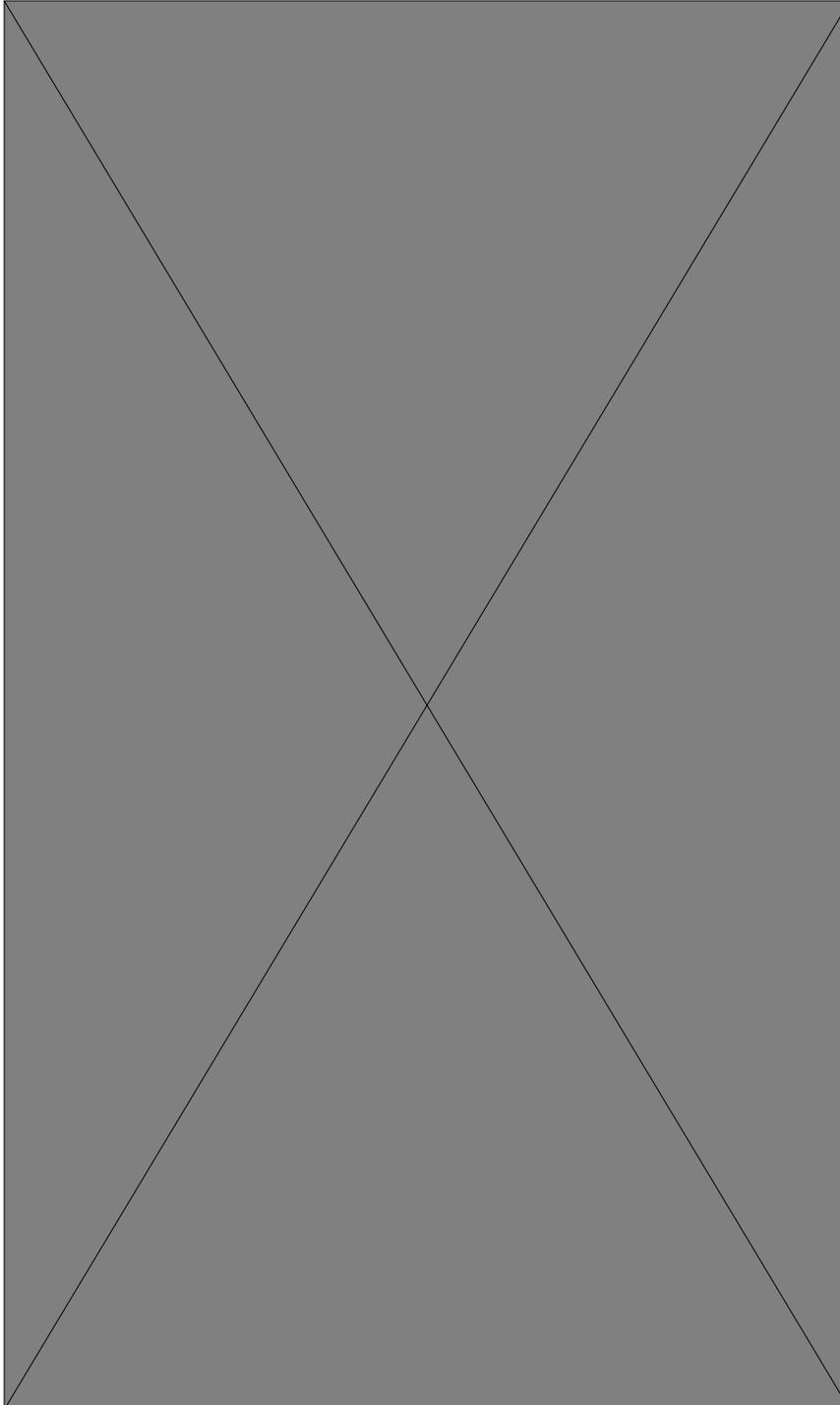
Cutting Suppliers Focus On Reliability

Suppliers are currently employing many different and creative strategies for improving temperature management in transit. Oftentimes, the key factor is the proper oversight of package handlers at the airlines and freight carriers. While the proper procedures are put into place at the beginning of each shipping season, it is critical to make sure that the procedures are being properly implemented. Suppliers are sending more dataloggers in boxes than ever before. These loggers provide vital feedback at identifying potential weaknesses in the cold chain.

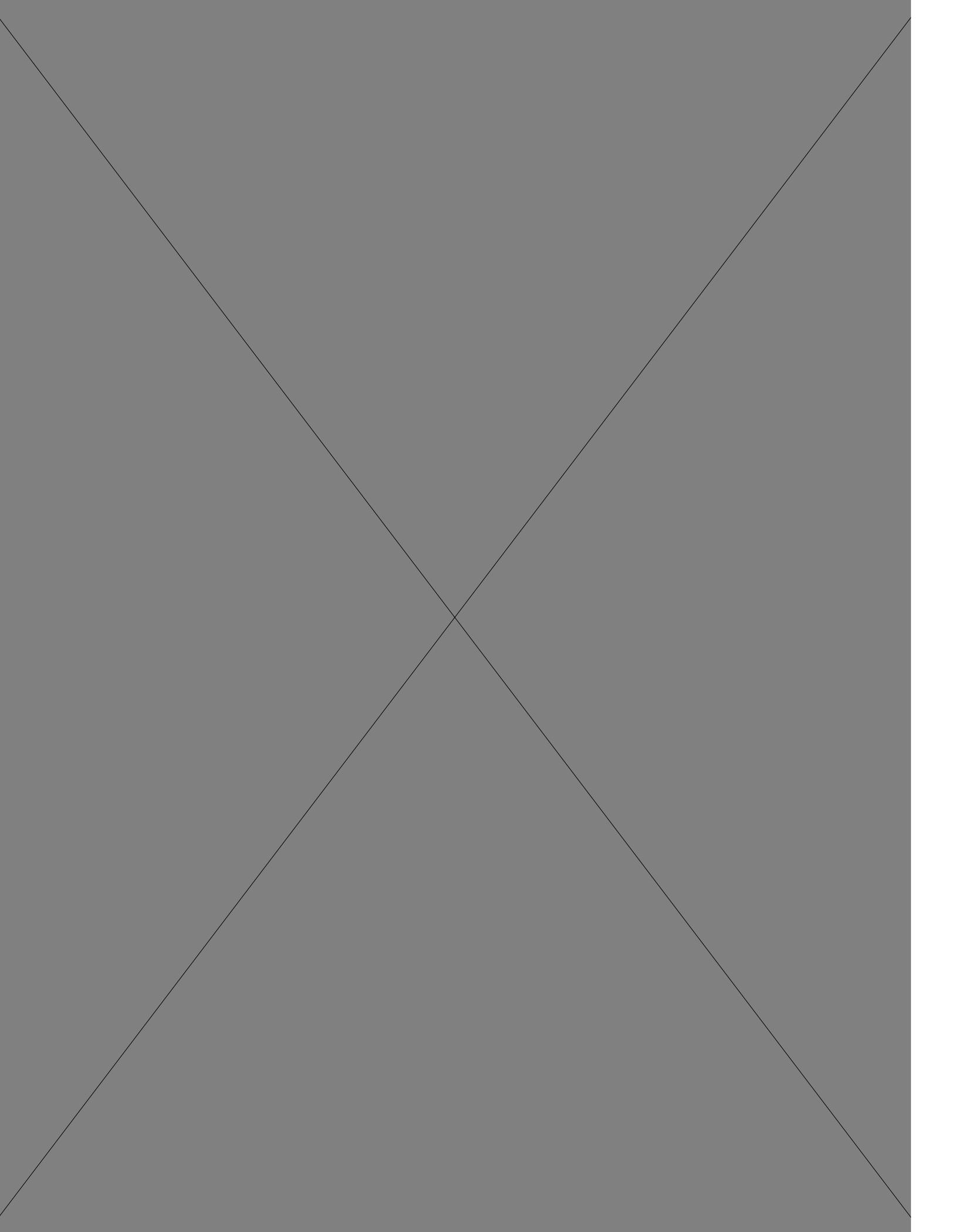
The ideal amount of ice and insulation in the packaging used for shipping cuttings will vary with the ambient weather conditions. Therefore, cutting suppliers are adapting their boxes with the season and sometimes even week-to-week in order to hit the target temperatures as accurately as is possible.

Handling Shipments Of Unrooted Cuttings

How the recipient of the boxes handle the product is just as important as



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all the other links in the cold chain. So what are the best management practices for handling boxes of cuttings?

- **Stick cuttings as quickly as possible.** This exposes the plants to sunlight and begins the recovery process, while it also removes the plant from the package and reduces exposure to ethylene. The reality is rapidly sticking the cuttings is not always practical, especially when freight deliveries come

in the afternoon.

- **Understand how sensitive the species is to shipping stress.** Species that are difficult-to-ship should be unboxed and stuck ASAP, no questions asked. This list includes: lantana, portulaca, heliotrope, 'Diamond Frost' euphorbia and Margarita sweet potato as well as others. Poinsettia and geranium should also be included in the list of moderately sensitive species. It is important to remember that there is

a considerable amount of variability amongst cultivars, so the urgency will vary with cultivar. In some cases you may consider sticking the sensitive cultivars first, then stick the remainder of the order the following day.

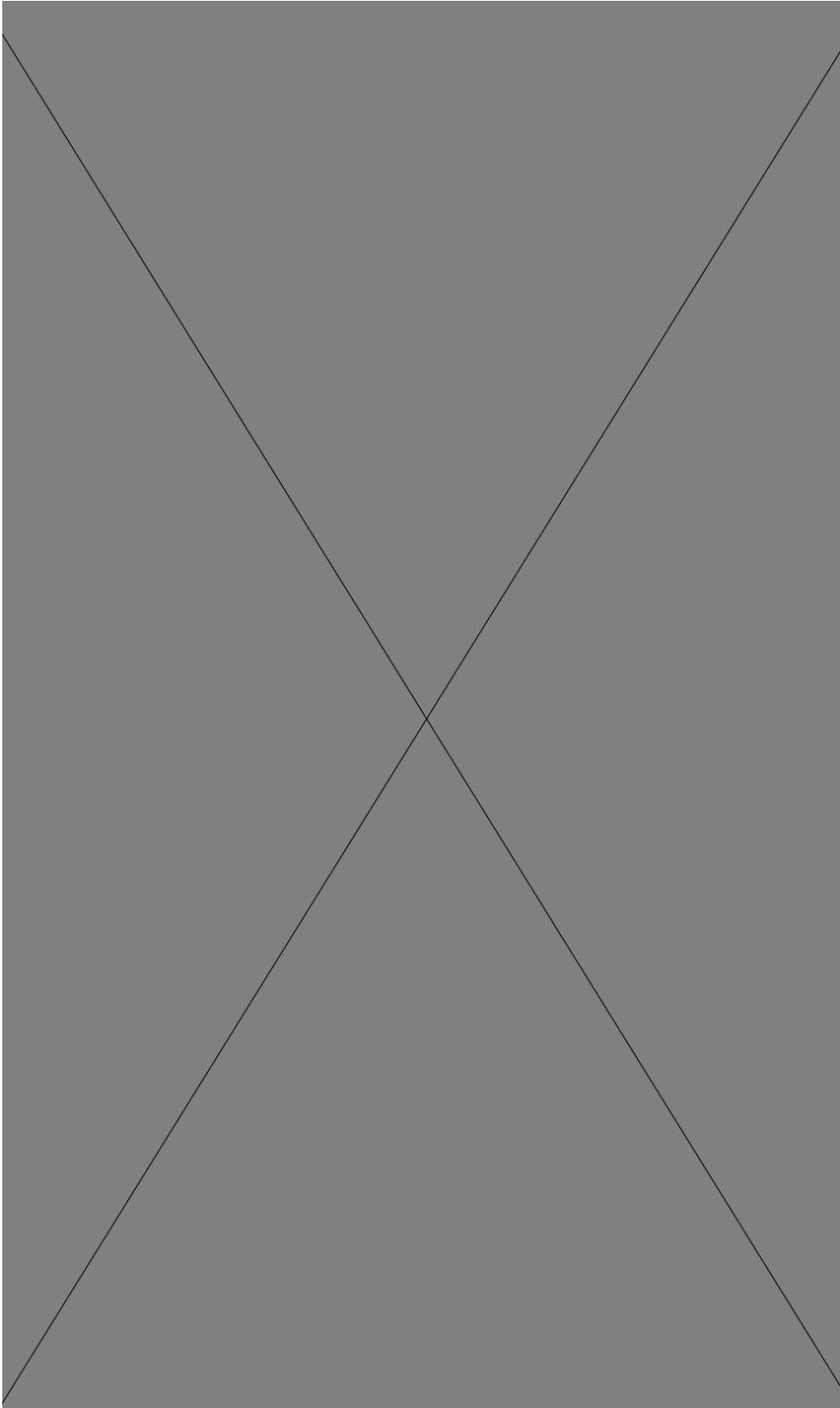
- **Check the temperature of the cuttings upon arrival.** Open a few boxes and measure the cutting temperatures with an infrared temperature gun. If the temperatures are below 60°F, then the boxes can be placed directly into a 50°F cooler. If the temperatures are above 60°F, then placing whole boxes into a cooler will not drop the temperatures to desirable levels rapidly enough. Warm boxes need to be opened up and the cuttings should be placed on racks in a cooler. The important thing to note is that a full box of cuttings does not cool down quickly. We have placed warm boxes in coolers for 24 hours and they still have not dropped down to the actual cooler temperature.

- **Has the delivery been delayed?** If yes, then getting the boxes opened and the cuttings stuck is all the more important. Again, we are simply trying to minimize the time in the box and the exposure to temperatures above 60°F. Also, delayed delivery often means the boxes have likely been in the back of a freight company truck that lacks temperature control for a longer period of time. Thus, exposure to non-optimal temperatures is more likely and the importance of handling the cuttings quickly has increased.

- **Is it better to place trays of cuttings onto a prop bench even if they won't get stuck today or should those cuttings go into a cooler overnight?**

If it is summertime and the greenhouse is quite hot in the afternoon, then placing the cuttings in the cooler overnight and sticking them the next morning is preferable. This is often the case with poinsettias. If it is wintertime and the greenhouse can be relatively cool and the bottom heat is shut off, then the cuttings can be placed on the mist benches, exposed to a few hours of sunlight and then stuck the following morning. This is often the case with geraniums.

- **Is dehydration a problem in the cooler?** Possibly yes. While transpira-



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tion and evaporation are lower at cool temperatures, some coolers are quite



After being exposed to 41°F temperatures for several days, this Blackie Sweet potato exhibits chilling injury.

dry and have a lot of air movement. These conditions can desiccate cuttings held overnight. In dry situations, additional plastic film or moistened paper may need to be placed over the racks of cuttings to keep the humidity levels up. Water can also be applied to the cooler floor to increase humidity levels.

- **Do the cuttings need to be removed from the plastic bags?** Most suppliers use bags that have enough holes to allow ethylene to diffuse out of the bags. Simply getting the bags out of the box is helpful.

- **What temperature should the cooler be?** If just one temperature is possible, then 50°F works for the majority of species. Some species, like geranium, prefer 40°F, but this will cause chilling injury on many spring species, so 50°F is good compromise. There are also some tropicals that require 55°F, so in these cases we have to compromise with 55°F.

- **What should the light levels be in prop?** During the first week or two in propagation, we prefer a maximum of 1000 footcandles or 4 moles/day, if you

have a sensor that accumulates light levels. Lower levels cause cuttings to recover more slowly from the low carbohydrate levels created during the post-harvest environment.

The bottom line is that every hour in a warm box is one hour too many. All your effort should focus on keeping the boxes cool and reducing the amount of time the cuttings spend inside a box. The sooner the cuttings get placed into the light on a prop bench, the sooner they begin to recover and refill their supply of carbohydrates. Paying attention to these small details will improve your success in propagation. **GG**

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