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Package Design & Cold-chain Management for Unrooted Cuttings

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BACKGROUND

Unrooted cutting (URC) performance following shipping is determined by the post-harvest conditions to which the cutting is exposed. Temperature is the predominant post-harvest factor that impacts cutting performance. URC's are shipped via air freight, thus post-harvest temperatures are highly variable. Temperatures and package design impact the gaseous environment inside commercial packages. As temperature increases the carbon dioxide and ethylene concentrations increase, while the oxygen concentration decreases. The gaseous composition of the package can cause physiological damage or may actually improve post-harvest performance.

The objective of this project was to determine the best methods for packaging and handling URC's in order to maintain the cold chain and the proper gaseous composition in the package from the cutting supplier to the propagator.

MATERIALS AND METHODS

A series of experiments were conducted to determine the effect of packaging materials and strategies on temperature and gas management in the post-harvest environment. We examined factors such as: ice position in box, ice mass, ice shape, insulative properties of the boxing materials (styrofoam sheet thickness, cardboard layers, plastic films), and the permeability properties of the plastic films to carbon dioxide, oxygen, water vapor and ethylene. [Note that we used frozen gel that has similar thermal properties compared to water.]

RESULTS

Cooling Methods

Removing field heat quickly from the cuttings is the first important step in maintaining the cold-chain. Most facilities use forced-air coolers; however these are frequently operated incorrectly. It is critical that the cuttings stay in the cooler for a long enough period of time to bring the plant temperature to be equal to the air temperature. The actual time of operation will vary with the initial cutting temperature and the mass of the cuttings placed into the cooler.

Initial Ice Temperatures

The initial temperature of the ice varies considerably depending on the freezer temperature and the amount of time the ice is outside the freezer prior to being placed into the box. Oftentimes, growers only note that the ice is still frozen when placed into the package, however this only indicates that the temperature is <32F. Thus, freezer temps should be known and the time for removing the ice from the freezer to boxing should be minimized.

The Phase Change Dilemma

A major challenge of shipping URC's is that the optimal temperature is frequently between 40 and 55F for most species. In contrast, the phase change from solid to liquid occurs at 32F and this is where the most energy is consumed. Thus, the ice or gel is most effective at temperatures below our target. Ideally, the phase change would occur near 50F. [Materials that have these properties are being developed

but are currently not cost-effective for shipping URC's] The dilemma is that if the cuttings are maintained in environments near the optimal temperatures during the first day of shipping, then the ice will melt and drop the temperature cooler than optimal. Then, the cuttings may be moved to a warm environment and the ice is no longer valuable as it has already undergone it's phase change (melted) prior to the box exposure to high temperatures.

Ice Position & Shape

Theoretically, ice placed along the sides of the box is best because it absorbs the heat coming from the exterior of the box prior to the plants warming up; however, our results showed that ice placed in the center of the box maintains the temperature of the box for a longer duration. The larger mass of one ice bag results in a greater duration of cooling compared to six smaller bags.

Styrofoam Sheets

The thickness of the foam sheets improves box temps as long as the box is primarily moving from a cold environment to a warm environment. However, thicker foam sheets have a negative effect after a box has warmed up and then is moved to a cooler location. In this situation the foam only serves to hold heat inside the box. Thus, the value of foam sheets varies depending on the environment to which the cuttings are exposed.

Insulative Properties of Other Packaging Materials

The cardboard and plastic films (including bubble-wrap) provide a minimal impact on the insulation properties of the package.

Ice Timing

We have recorded temperatures in dozens of internationally-shipped packages of cuttings. The first day of shipping occurs in the producer's cooler and trucks, the airport coolers and the airplane to the U.S. In general, temperature management at this time is acceptably good. The worst temperature abuse tends to occur in the second day of shipping (typically from Miami to the customer). Our experiments have demonstrated that icing boxes at the beginning of Day 2 of shipping is more valuable for proper temperature management. So, we have designed a box that allows the user to jam a cylinder of ice into the center of the box without having to open the box at the U.S. Port-of-Entry.

Package Ventilation

Sealed bags cause severe physiological damage to cuttings when temperatures are warm (>60F). Carbon dioxide toxicity tends to occur before low oxygen (anaerobic) conditions occur. Excessive ethylene (>1ppm) is also common in densely packed boxes. While large holes are not required to prevent these problems, it is possible to have excessive ventilation that results in plant dehydration. We are currently developing a model to predict the optimal package hole size as a function of the amount of plant material in the package (fresh mass).

Temperature Tracker

An Excel spreadsheet has been developed to quantify temperature stress of packages in transit. Data collected from a simple datalogger can be imported into the spreadsheet and the number of degree-hours above or below the optimal shipping temperatures are calculated.

IMPACT TO THE INDUSTRY

Post-harvest temperature management is a dynamic situation. There is not a single answer to the question of how to build a better box for maintaining the cold-chain. Our data and results are currently being used by cutting suppliers to make weekly decisions as to the proper box designs. Thus, the best box/ice/insulation design varies week-to-week based on the ambient shipping climate in the U.S. These frequent decisions allow for improved cold-chain management and improved cutting performance for U.S. propagators.

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