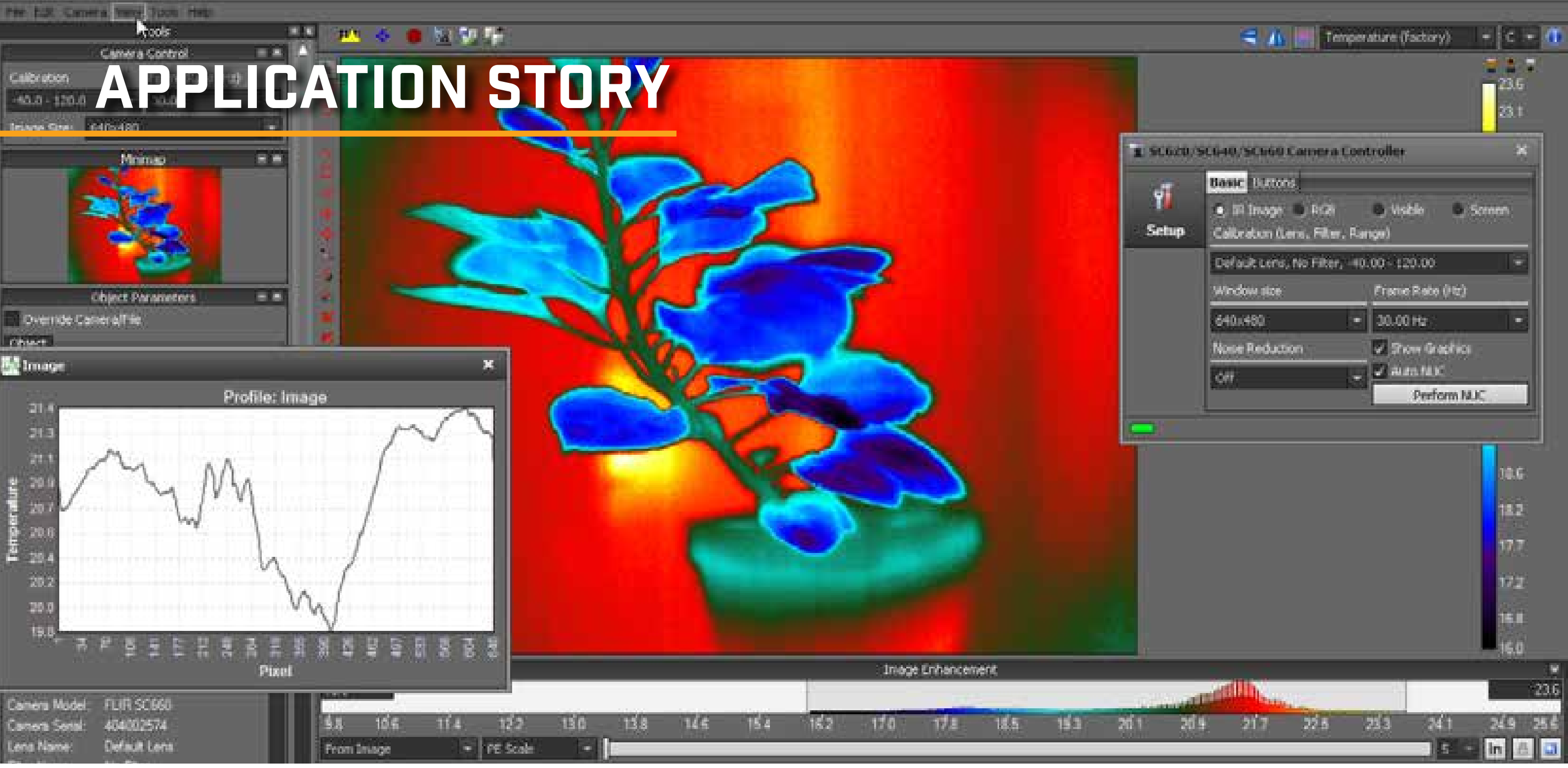
APPLICATION STORY



FLIR CAMERAS HELP RESEARCHERS STUDY ICE NUCLEATION AND ICE PROPAGATION IN PLANTS.

Figure 1: ResearchIR is powerful and easy-to-use thermal analysis software for camera system command and control, high speed data recording, real-time or playback analysis, and reporting. The insert on the right shows the options for changing camera settings. The insert on the lower left shows a temperature histogram of the live image.

Spring frosts can be lethal to many growing plants. They can have devastating effects on agricultural production and increase consumer prices. The freezing process of plants is very complex and scientists have used various methods to monitor and research it, including thermal imaging cameras. This technology has already led to new insights on how plants freeze and on what can be done to protect plants from freezing.

Whenever a severe spring frost occurs, it seems that farmers can only stand by and watch their crops going to waste, especially when such an episode is preceded by the early onset of warm weather, stimulating plants to grow. These erratic weather patterns seem to be occurring worldwide more often in recent years and the use of the few tools available for frost protection is often futile. Partially to blame for the lack of effective tools for frost protection is our continuing lack of knowledge about what makes plants freeze at any particular temperature and what types of frost protection methods should be used for different weather scenarios.

VISUALIZING THE FREEZING PROCESS

At the Agricultural Research Service of the US Department of Agriculture (USDA-ARS), researchers are using high-resolution thermal imaging cameras from FLIR Systems to visualize the freezing process in plants. Michael Wisniewski and David Livingston, USDA-ARS researchers, have stated: "With these thermal imagers, we can determine the primary sites of ice formation in plants, how ice propagates and the presence of ice barriers. The use of high-resolution thermal imaging allows us to visualize the many adaptations that have evolved in plants, which directly or indirectly impact the freezing process and ultimately enable a plant to survive frost events. With a thermal imaging camera, we can see where active sites of ice nucleation are located, and how ice formation initiates and spreads into the surrounding tissues."

Ice nucleation can be induced by either or both extrinsic and intrinsic nucleators. Ice nucleation-active bacteria and moisture are two major extrinsic agents. In herbaceous plants, the influence of extrinsic ice nucleators on ice

Figure 2: Freezing experiment being conducted on a bean (Phaseolus vulgaris) bean plant. Drop of Ice-nucleation-active bacteria (INA) (Pseudomonas syringae) and a drop of water are placed on the left, and right side of leaf, respectively. As the temperature drops, the INA droplet will freeze and initiate freezing in the rest of the plant. (courtesy of Dr. Michael Wisniewski – USDA-ARS). Taken with a FLIR Model A6700SC.

nucleation can be moderated by hydrophobic barriers. Woody plants however are different. These plants seem to have intrinsic nucleating agents, although they also have barriers that inhibit the spread of ice. It is very important to know the role of these nucleators in ice formation, because if methods can be developed for regulating ice nucleation, significant advances can be made in limiting frost injury to freezing sensitive plants.

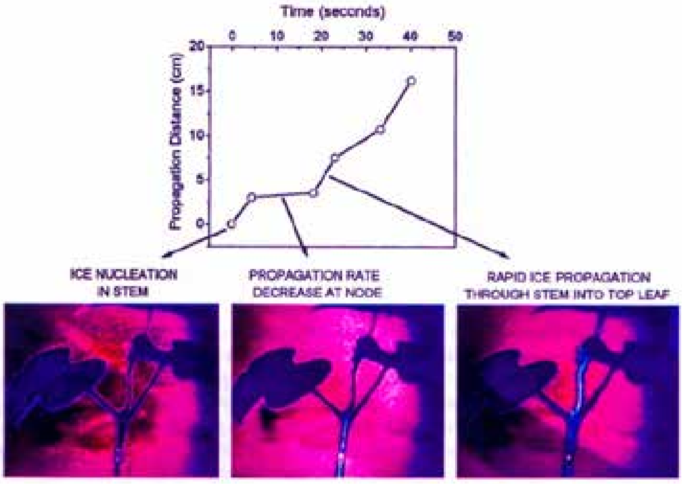


Figure 3: Rate of ice propagation in a bean plant (Phaseolus vulgaris) calculated using infrared thermography. A. Ice initiated in stem (arrow). B – C. Ice propagation up and down the stem. Graph at top of figure displays the rate of ice propagation presented as the distance ice traveled over time as it moved up the stem from the original site of freezing. A delay in ice propagation occurred as ice moved through the nodal portion of the plant stem. This figure was modified from Wisniewski et al.

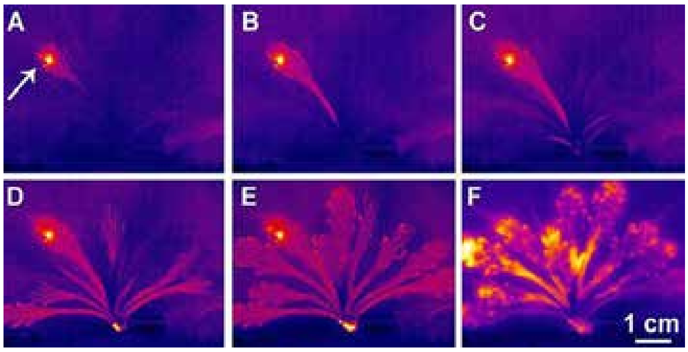


Figure 4: Ice nucleation and propagation in the alpine plant, Senecio incanus. Freezing is initiated in the top portion of a leaf (A) and then spreads downward (B-C) into the basal portion of the leaf, and then back up into the remaining leaves. (courtesy of Dr. Gilbert Neuner, University of Innsbruck, Austria). Taken with a FLIR S60.

THERMAL IMAGING VERSUS THERMOCOUPLES

Various methods have been used to study the freezing process in plants under laboratory conditions, including nuclear magnetic resonance spectroscopy (NMR), magnetic resonance imaging (MRI), cryo-microscopy, and low-temperature scanning electron microscopy (LTSEM). Freezing of whole plants in laboratory and field settings, however, has mainly been monitored with thermocouples. Even though these have been the typical method of choice in studying freezing in plants, the use of thermocouples has many limitations that limit the amount of information obtained during a freezing event.

"With thermocouples, you cannot monitor the plant as a whole, so it is nearly impossible to determine where ice is initiated in plants, how it propagates, if it propagates at an even rate, and if some tissues remain free of ice," says Michael Wisniewski. "It is also intrusive: you have to insert or tape a thermocouple onto the plant. And strikingly, we have noticed that the point where a thermocouple is inserted in the plant can sometimes serve as a site of ice nucleation, thus providing erroneous data."

The FLIR A6700sc is a mid-wave, science-grade thermal imaging camera with a highly sensitive 640x512 pixel resolution.

Michael Wisniewski (USDA-ARS), has been using several models of cameras from FLIR systems for the past decade as the method of choice to study ice formation in his freezing research. His use of this technology revolutionized plant freezing research and several research institutions worldwide are also using FLIR cameras to study the freezing biology of plants, including David Livingston, USDA-ARS (freezing in crop plants), Gilbert Neuner, University of Innsbruck, Austria (freezing tolerance of alpine plants), and Larry Gusta and Karen Tanino, University of Saskatchewan, Canada (freezing in crop plants).

"Thermal imaging cameras have many advantages over thermocouples," says Michael Wisniewski. "The cameras allow you to see the ice formation even in its initial phase and monitor the entire plant non-intrusively, rather than small isolated portions of a plant. Using this technology, it is possible to determine the role of extrinsic and intrinsic nucleating agents in the freezing process, and how the specific pattern of freezing relates to visual patterns of injury. You can actually observe how ice is propagated in a plant and if any barriers to ice propagation are present."

"Thermal imaging cameras from FLIR also allow you to make long video recordings and then only use the parts that are interesting afterwards. That is important because you never know up front when an event is going to happen, so the ability to monitor continuously is essential."

"Another important benefit of FLIR cameras is that they are extremely rugged and that they allow you to go outdoors, and conduct research in the field, instead of in an artificial lab environment."

SCIENCE-GRADE THERMAL IMAGING CAMERA

The exothermic events that are being visualized during the freezing of plant tissues are often very small, ranging from <0.1 to about 0.5 °C. Therefore, the infrared camera must be sensitive enough to easily differentiate small changes in temperature. Temperature accuracy is also an important aspect, especially for temperatures below 0°C. After having used several FLIR camera models, the USDA evaluated FLIR's A6700SC, a mid-wave, science-grade thermal imaging camera with a highly sensitive 640x512 pixel resolution. "In terms of image accuracy and sensitivity, the FLIR A6700SC is exactly what we need," says Michael Wisniewski. "We are extremely satisfied with the image quality of this cooled camera, its ruggedness and ease of operation. We have also used various lenses, to conduct extreme close-up observations of our work."

USDA researchers also make use of FLIR's ResearchIR software. The software is used to view the live image, change camera settings, record single images, make video recordings, and analyze temperature data in the images (Figure 1).

For more information visit
www.flir.com/research