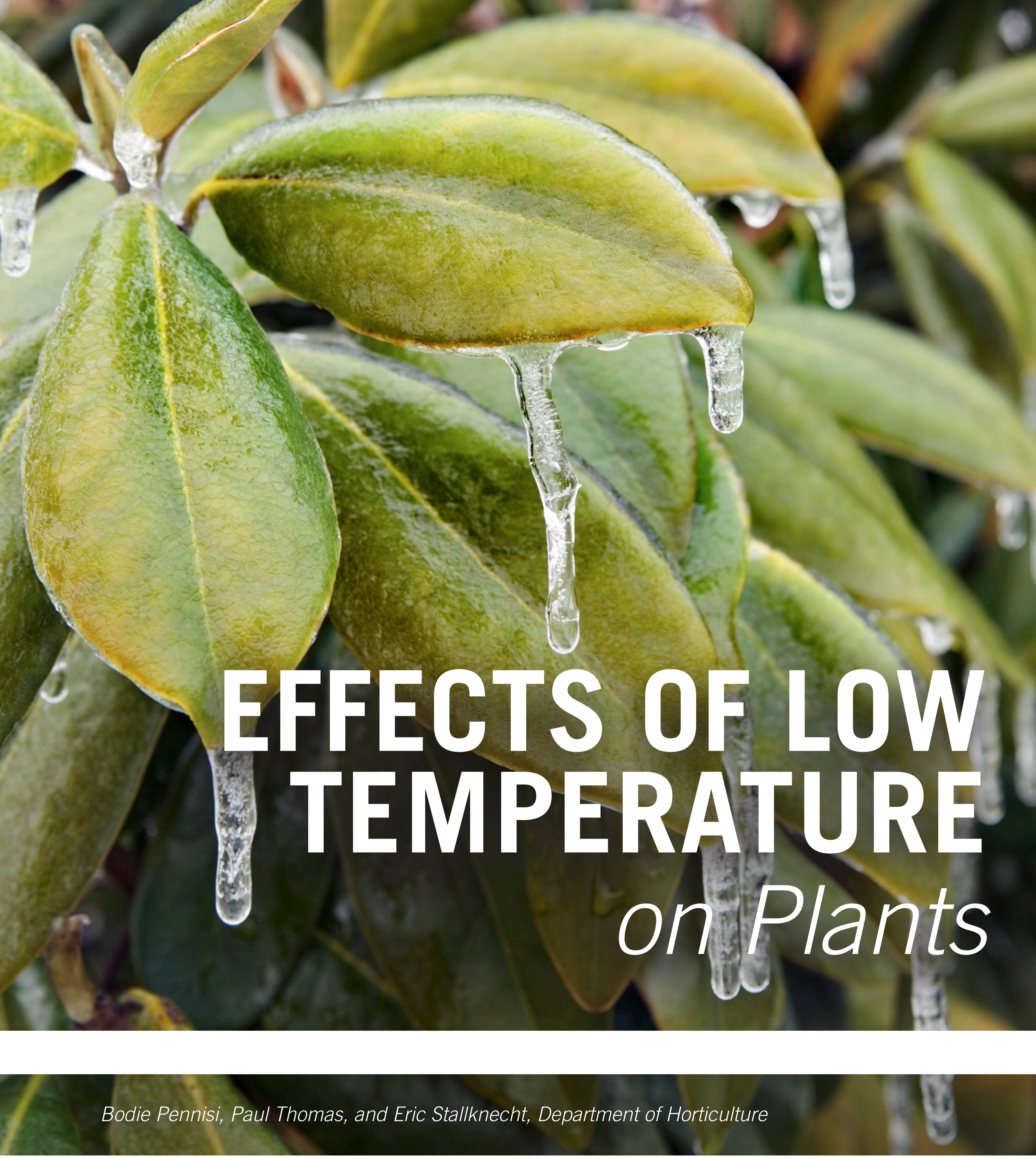

EFFECTS OF LOW TEMPERATURE *on Plants*

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EXTENSION

Temperature is an important environmental factor in plant growth and development. It governs the rate of photosynthesis (food production) and respiration (food utilization). Depending on its origin (e.g. tropical or temperate), each plant species has a temperature range where it grows best. Temperature greatly influences plant hardiness, fall color, and senescence (leaf fall). A plant's hardiness determines its ability to withstand the average minimum temperature of a region without damage or death. Although winter hardiness is genetically determined, it is influenced by the duration of cool temperatures. Cool temperatures acclimate plants and prepare them for winter dormancy. Many woody plants need two to four weeks of cool temperatures to achieve maximum hardiness. The United States Department of Agriculture Plant Hardiness Zone Map (Figure 1) shows the cold hardiness zones of Georgia. Zones are based on average minimum temperatures in a region. As temperature is the least controllable environmental factor in landscapes, growers should select species rated for their appropriate hardiness zone(s).

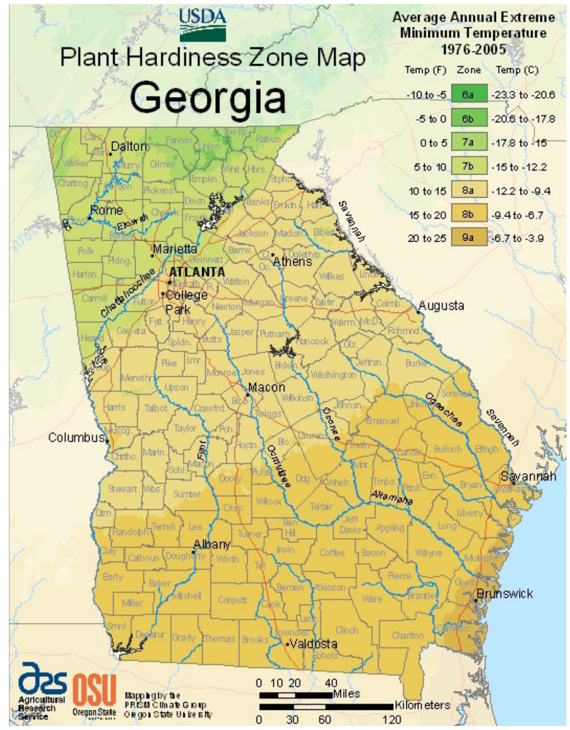

Figure 1. Plant Hardiness Zone Map of Georgia. Zones are based on average minimum winter temperatures. Zones are not permanent and change over time. Keep an updated map to ensure best results for your specific region.

For example, you should *not* attempt to grow plants rated with hardiness zone 8 (warmer) in zone 7 (cooler) because they often become damaged by winter cold. Conversely, zone 6 plants are fine for zone 7 provided they are also heat hardy and adapted to the soils of the area. If you choose to grow plants with borderline hardiness, you should be prepared to provide cold weather protection. Having a solid grasp of cold temperature's effects on plants will help you implement critical horticulture practices like controlling greenhouse temperature, insulating containerized woody stock, and correctly timing any pruning.

In this publication, we will explore the effects of low temperature on plants in production greenhouses, nurseries, and landscapes. These three environments have different causes and effects, each requiring unique responses to avoid injury. To better understand the effects of low temperatures, let's look at how and when freezing and chilling injuries occur.

Freezing and Frost Injury

Freezing and frost injuries occur at or below the freezing point (32 degrees Fahrenheit/0 degrees Celsius). Freeze damage happens during an advection freeze when an air mass with temperatures below freezing moves into an area and displaces warmer air, causing the temperature of plants to become low enough for ice crystals to form inside their cells. Frost damage happens during a radiation freeze. This occurs on clear nights without wind when plants radiate more heat to the atmosphere than they received. This creates a temperature inversion where cold air close to the ground gets trapped by moist, warmer air above it. When air temperature at ground level nears or drops below freezing, the plant's temperature becomes colder

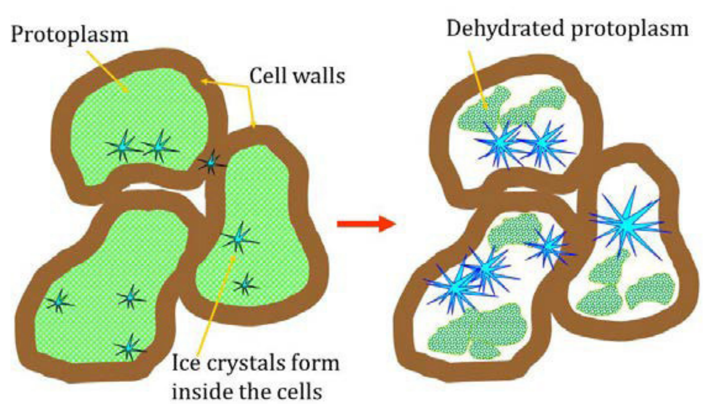

Figure 2. As ice crystals grow, they attract water from the cell, dehydrating and killing the living protoplasm.

than the surrounding air temperature, causing ice crystals to grow on the surface of the foliage, stems, and flowers. During both frost and freeze injury, ice crystals form in plant tissues, dehydrating cells and disrupting/rupturing plant membranes (Figure 2). This causes physical damage as expanding rigid ice crystals puncture cellular membranes, and dehydration damage as all water within plant tissues freezes, rendering it inaccessible for photosynthesis.[1] Once physical damage has occurred, it manifests itself as brown to yellow necrosis, often leading to portions of the plant or the entire plant dying. Cold hardy species are less susceptible to freezing and frost injury (Figure 3).

Figure 3. Frost appears on leaves (top, yaupon holly) and flowers (bottom, pansy). Within an hour or two of the sun shining, the ice evaporates. Both species are cold-hardy and will not be damaged.

Chilling Injury

Chilling injuries occur above the freezing point (32 F/0 C), and plants of tropical and subtropical origin are most susceptible. Injured foliage appears purple or reddish (Figure 4), and sometimes wilted (Figure 5). Chilling injury can be obvious or invisible. Chilling can delay crop blooming, cause direct damage, or reduce plant vigor. Chilling injury happens often with tropical and subtropical plants grown in most of the U.S., but can happen with native, temperate forest plants as well, depending on critical temperatures, the duration of low temperature, temperature changes, age, hydration status of plants, and time of year (Figures 5 and 6). Plants can drop damaged leaves, become wilted, produce misshapen new growth, display discolored foliage, or even have whole or portions of the plants dying. The damage may also be unseen by the naked eye but manifest later as delayed blooming or stunted growth.

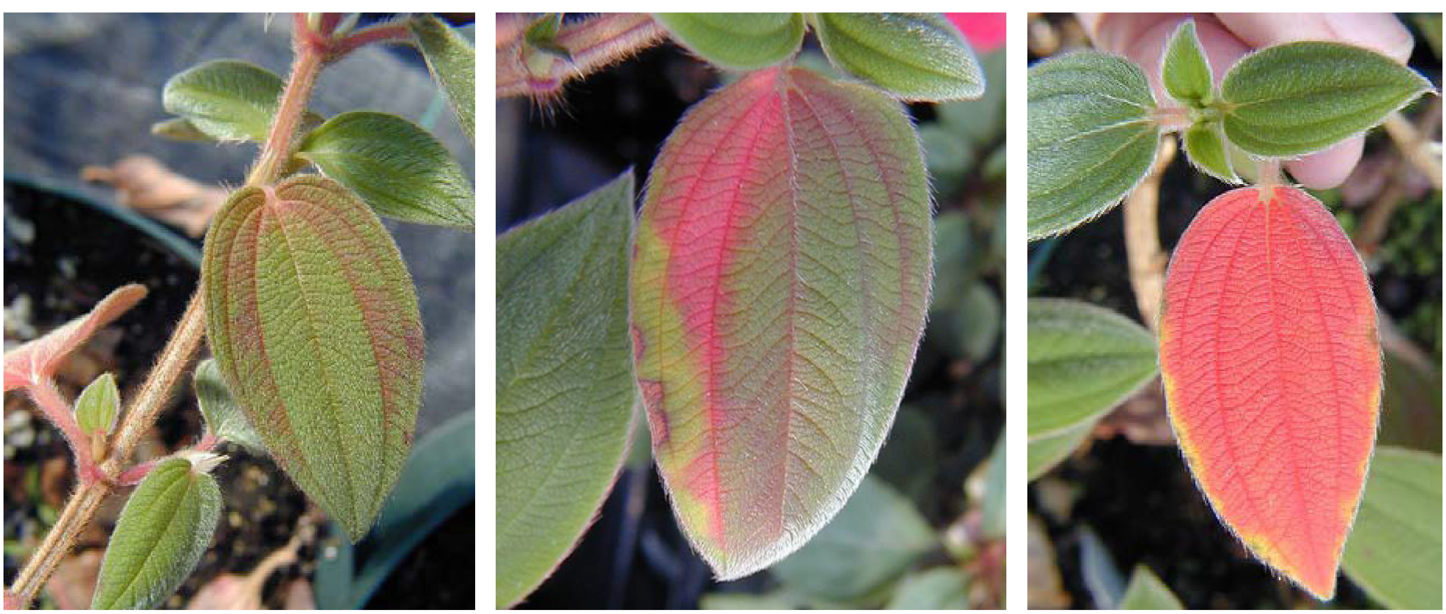

Figure 4. Chill damage on princess flower, *Tibouchina urvilleana*, is manifested by red lower foliage. The damage is fairly mild, although the affected leaves will defoliate. This type of damage is common in early fall.

Figure 5. More severe chill damage on ginkgo is manifested by wilted foliage. This damage is common in late spring when plants have come out of winter dormancy and have started developing young foliage.

Figure 6. Chill damage on Indian hawthorn. Mature foliage turns brown to dark brown or nearly black. This type of damage can occur throughout winter.

In many cases the most exposed part of the plant canopy becomes injured after low temperatures (Figure 7), often causing entire shoots to die (Figure 8).

Every plant is a living entity with unique preferences for temperature. Specific temperature ranges are required for optimal functioning of enzymatic and biomolecular processes. These processes make proteins and sugars, the building blocks of plant cells and tissues, and carry out cell functions leading to plant growth. For example, temperatures could be near 100 F for a cucumber, or near 50 F for Primula. It is often not the temperature that specifically causes the damage. ***The extent of damage is determined by factors including the amount of temperature change, the stage of growth, and the speed and duration of change.***

Figure 7. Chill damage on gardenia (left) and Carissa holly (right). The most exposed parts of the canopy were affected. The gardenia shoot tips turned brown. New shoots developed later in the spring, emerging below the damage. This is frequently referred to as "frost pruning."

In the case of the holly, only the tips of the exposed foliage were damaged.

Effects of Rapid Chilling

Figure 8. Chill damage on azalea. Instead of the tips, an entire shoot was affected and had to be removed.

Plants are an extremely complex set of chemical reactions. Everything including basic cell materials, such as water and nutrients, proper levels of enzyme activity, and appropriate environments must be in place for plants to grow well. These processes take time to allow plants to adapt to different temperature regimes. As a whole, this is called "acclimatization," which can take hours, at best, and days or more for many plants. For some tropical interiorscape plants, up to 6 months may be needed. Therefore, the amount of damage first depends on how rapidly that species can adapt.[2] For example, in order to adapt, foliage may have to change the orientation of the leaf itself or change the orientation of chloroplasts and the photosynthetic apparatus (the food-making parts of the cell). Consider also the rate of activity of such complex processes as photosynthesis and respiration. As mentioned previously, temperature has an important effect on the rate of the biochemical reactions. This effect is known as the "Q10" and it refers to how a biological reaction responds to a change in temperature within the temperature limits of a plant. Tropical African Violets, for example, prefer to grow in temperatures between 56 and 80 F. Just outside that range, they will slow down but survive. Most plants have a Q10 of 2, which means that for every 10 degree Centigrade increase in tissue temperature, the reaction rates can double (within the temperature limits of that plant). So photosynthesis rates can double between a cool morning and a hot afternoon. In reverse, respiration rates can be cut in half between a warm afternoon and a cool night. ***Basically, things react faster when warm, and slower when cold.***

There are also limits as to how fast the change from hot or cold can happen before the plant can't adapt to temperature shifts. Some species cannot respond quickly enough, and when change occurs, parts of the system stall, break, stop, or cease to exist. An African violet grown in a greenhouse (60 F in the morning) is not going to go into shock when watered with 55-degree-F hose water, because the difference in temperature is very small, so you see few, if any, chill spots (Figure 9). On the other hand, that same plant watered in the afternoon (90 F air temperature) will experience physiological stress such as disruption in cell and chloroplast membranes (3). Given a few minutes to an hour, the cell either dies or survives without key enzymes, chloroplasts (hence yellowish cells or spots) or adequate membrane integrity (Figure 9). If the chilling damage affects many leaves on the plant, growth slows and death can eventually occur. No amount of nitrogen can help the plant recover. Even watering a warmed-up African violet at 3:00 pm on a summer day with 65 to 70 F water can cause spotting. One final note: cold water below 55 F exceeds the cold temperature limits of an African violet plant.[3] If the greenhouse outdoor cistern water drops to 45 F in a cold snap, the crop of African violets can be severely damaged if you use that water directly, regardless of how cool the greenhouse night temperature was or how early the crop was watered.

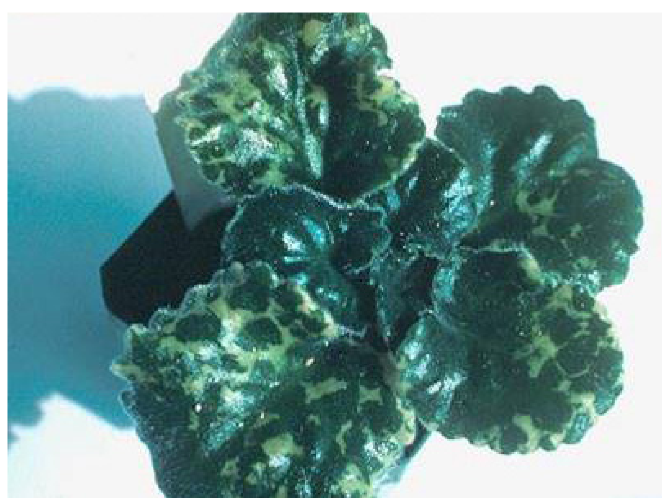

Figure 9. Cold water damage on African violets.

Now that we have established what frost/freeze damage, chilling injury, and rapid chilling injury are and how they affect plant cells and tissues, we can adapt cultural practices to prevent this in different environments. Greenhouses, nurseries, and landscapes each require specific techniques to prevent low temperature damage. ***Remember: prevention is the key, and philosophically, all environments require constant prevention to ensure healthy plant growth.*** We will suggest a few key cultural practices and some examples for each of the three environments. These are not complete lists, however, and knowing a plant's physical boundaries ensures proper health. If you're unsure about a decision that affects entire crops, make sure to consult your local county Extension agent.

Greenhouses:

It's important to prepare for cold temperatures. Frost and freeze damage occur in the same manner as in the environment. Greenhouses offer substantial protection to cold-sensitive plants, but they must function properly to ensure that. In polyethylene-covered hoop houses, placing two layers over the frame creates an insulated pocket of air between them that resists greater temperature fluctuation than a single layer would. This helps prevent rapid temperature change inside the greenhouse. If propane heaters are available, inspect them before their inevitable use and periodically thereafter to ensure that they remain functioning. Depending on the size of the greenhouse, a temperature gradient can form in which the side closest to the heater will remain warmer than the side furthest from the heater, and this temperature difference may cause uneven plant growth and cause crop delays. Plastic tubing running the length of the greenhouse can be used to help alleviate the temperature gradient for more even air distribution. In some cases, heated mating can be used to protect susceptible plant material.

Greenhouse crops such as lantana and vinca are notorious for not showing physical signs of chill damage from cold water on a warm afternoon. Bedding plants such as calendula and angelonia are examples of plants whose new expanding growth will distort easily when exposed to a rapid temperature shift. Damage caused to the photosynthetic pathways have long-lasting effects, often over weeks, and can manifest itself by slow growth. Root tissue, especially in bedding plants and vegetable starts, can be dramatically affected by rapid shifts in soil temperature. Mineral uptake by the root is impaired because of the cold effects on the root hair membranes. ***Deficiencies can occur even when adequate nutrition is present in the soil.*** If plant foliage is touching the cold greenhouse glazing, that could lead to damage as well.

Boston fern grown in baskets (Figure 10) is a popular spring crop. Boston fern is not adapted to large temperature swings. If the night temperature chills rapidly, they will develop foliage with misshapen leaflets and twisted fronds (Figure 10). This is why spring-grown ferns can be damaged by energy-saving attempts to lower the heat at night: not enough time is given to the plants to adapt to the lower temperatures.

Research has shown that plant cultivars may have differences in chill sensitivity. A paper recently published out of the University of Florida IFAS Extension evaluated *Spathiphyllum* hybrids for sensitivity to chill damage.[3] Results from the study showed

Figure 10. Chill damage on Boston fern.

leaf chill damage by 38 F temperatures varied from 2.5 percent damage up to 100 percent damage. For *Spathiphyllum*, a temperate chill to just 38 F caused significant damage to appear within 24 hours. Many cultivars tested exhibited black leaves or large necrotic areas.

To minimize chill damage in greenhouses:

1. **Reduce cold air impact by using convection tubes when venting cold winter air in a greenhouse.**
2. **Do not drop night temperatures below the tolerance limit for that crop.**
3. **Know what your well water or city water temperature averages in spring and fall out of the end of the hose. Measure it at 7:00 and at 3:00 pm after running the water for 5 minutes! Water only in the morning, preferably before the heater or the sun warms up the greenhouse. In addition to reducing chill effects, you will reduce the potential for disease.**
4. **Reduce the rate of temperature drops by running HAF fans at all times in the winter to mix the air from vents or open doors.**
5. **Keep all leaves at least 6 inches from greenhouse sidewalls and external glass.**

Nurseries:

Acclimating deciduous woody stock before winter often occurs in above ground organs, leaving freezing damage to affect the roots of container plants. For this reason, you should be ready to protect the root system from freeze damage.[4] Both heated and unheated greenhouses can provide protection from winter freeze damage. Unheated greenhouses can be used in regions where periods of freezing temperatures from winter are short. Heated greenhouses may be used, but they should have temperature near freezing to keep them acclimated and not break bud too early, as this often causes severe damage. Even in winter, greenhouses can reach high temperatures. Opening vents and using high-air-flow fans can be used to cool a greenhouse with outside air to prevent this early bud break. Containers may be buried or insulated with mulch (or even hay) to prevent damage to sensitive roots over winter.

Water as Frost Prevention

Citrus and fern growers in Florida will sometimes spray water on the plants to reduce impending damage. Heat is given off during ice formation, so the ice doesn't penetrate the leaves and fruit tissue. This system works only as long as water is continuously applied. If the water stops, temperature will quickly drop below freezing and cause damage. This type of protection works well for plants with thick cuticle leaves and tough, thick fruits. However, when applied to perennials, many ornamental woody crops and bedding plants, results are far less successful. The rapid drop of temperature across the entire leaf is too rapid. Freeze damage is deadly, but chill damage is insidious and can have long-term effects. It is far better to use good quality frost cloths as recommended by the industry to slow the rate of cooling and keep the temperature as high as possible, or pile leaves up over your outdoor plants as insulation. ***Using water to prevent freezing brings leaf tissue temperature near 32 F, which for many, if not most, ornamental crops will still likely result in chill damage.***

Landscapes:

Low temperatures can negatively affect plants in the landscape. The easiest way to avoid low temperature damage is to pick and use plants according to their plant hardiness zones. These zones are based on average minimum temperatures and will prevent any cool or cold weather damage. When buying new stock, inspect the tag for the plant's hardiness zone. If it's not on the tag, this information is readily available on the internet and from store owners.

If you wish to grow plants in the landscape that are outside of your hardiness zone, there are a few things that can be done to help ensure they survive in the landscape. Place susceptible plants on the north and east sides of the home where the warm morning sun won't induce plants into early bloom or leafing. Place potted plants in a covered area, buried, wrapped in insulation, or mulched for extra protection. Cold damage can also occur from fluctuations in temperature. Roots can be susceptible to cold damage even if the aboveground portion is acclimated. Mulching the ground around its root ball will help prevent root damage.

Pansies offer a good example of cold-affected root systems when plants appear to be starving mid-January in the South in a tested, fertile bed. The near-freezing soil temperatures have impaired root uptake, but the relatively warm afternoons promote leaf metabolism and even flowers. The end result is that the plant must cannibalize nutrition from the leaves to maintain new growth or flowers despite the poorly performing roots. Nitrates are taken up better than ammonium ions at lower and higher temperatures than preferred by the plant. ***Award-winning landscapers use foliar-fed, nitrate-based, quick-feed fertility programs in winter to maintain flowering pansies.***

In summary:

1. Each plant has both hot and cold temperature limits that you *cannot* exceed. Know them.
2. Within preferred temperature limits, each plant has a different ability to respond to the amount of temperature change that occurs, either in minutes under a hose or over hours in an open field or greenhouse. The rapidity of that change matters greatly, and the duration of the shift matters as well. Most tropical and subtropical ornamental crops are sensitive to chilling! With woodies, perennials and native species, it depends completely on the species and stage of growth. Some are insensitive, and some are sensitive only when in a growth flush or when blooming.

References

[1]Kadohama, N., Goh, T., Ohnishi, M., Fukaki, H., Mimutra, T., & Suzuki, Y. (2013). Sudden Collapse of vacuoles in *Saintpaulia* sp. Palisade Cells Induced by a Rapid Temperature Change. PloS One (8) 18.

[2]Lukatkin, A.S., Brazaittyte, A., Bobinas, C., & Duchovskis, P. (2012). Chilling Injury in Chill-Sensitive Plants: A Review. Zemdirbyste Agriculture. Vol 99. No 2. P 111-124.

[3]Chen, J., Qu, L., Henny, R.J., Robinson, C.A., Caldwell, R.D., & Huang, Y. (2011). Chilling injury in Tropical Foliage Plants: Spathiphyllum. University of Florida IFAS Extension publication ENH841. 1-3.

[4]Barney, Danny L. (1991). *Winter Protection for Containerized Nursery Stock.* University of Idaho, Cooperative Extension System, Agricultural Experiment Station, College of Agriculture.

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