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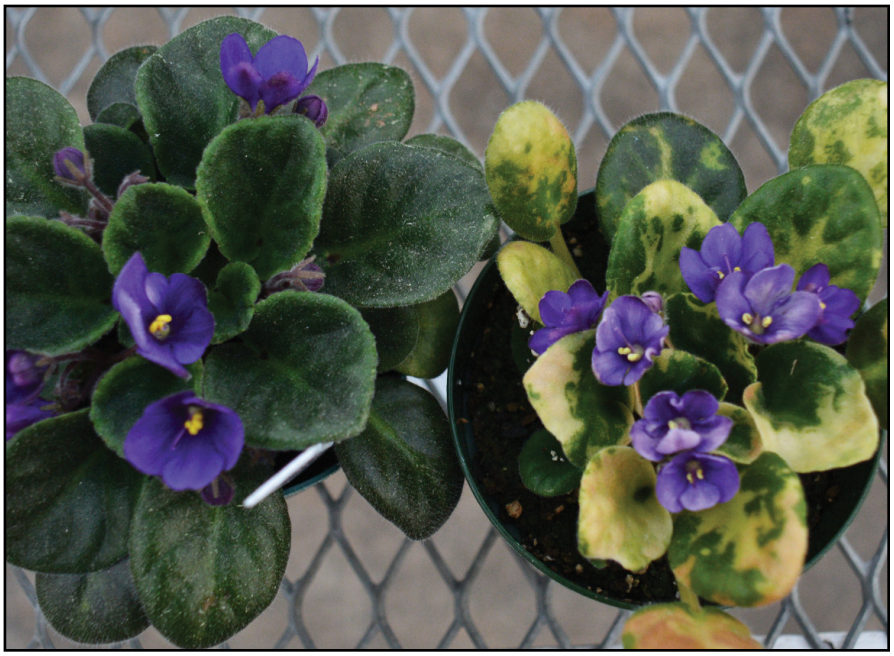
Chilling Injury: What It Is, Why It Happens and How To Avoid It!

Chill damage, or more specifically, damage caused by rapid changes in temperature can happen any time. Most commonly affected by chilling are tropicals, followed by subtropicals and temperate zone plants. Stage of plant development, the rate and degree of temperature change and the duration of the temperature outside the preferences of the plant all play a role in the severity of the damage.

Many parts of the South and Midwest saw a typical but late spring warm-up only to have a snowstorm or, at best, very cold rain cover their outdoor crops 10 days later. Not surprisingly, a few growers had left vents open or had turned off the heat to their greenhouses to save money. Water in greenhouse hoses became cold but didn't freeze. Growers reported dodging the frost bullet! All seemed well until a week or two later, when many reports came in asking about leaf formation maladies, lack of growth, and physical damage, and what looked like bacterial disease. The diagnosis: chilling injury!

Chilling injury can be obvious or invisible. Chilling can delay a crop blooming, cause direct damage or simply rob the plant of vigor. Chilling injury happens often with tropical and subtropical plants grown in most of the U.S., but can easily happen with native, temporal forest plants too, depending on when and how the chill event happens. What I'm about to say next may seem idiotic: we often see chilling injury in some greenhouse plants in the middle of the summer when



Two identical cultivar African Violets grown just feet apart, one watered in the early morning weekly by a student, the other at 5:00 pm weekly by another student. The difference in appearance is significant. Leaf temperature matters!

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the day temperatures are in the 90s and the nigh temperatures are in the 70s! How can that be? Let's explorer...

First we must establish a few ground rules. Every plant is a living entity. It has unique preferences for temperature, just as people do. Those preferences have to do with the temperature range that the plant's enzymatic and bio-molecular processes require. Better put, it has to do with the temperature at which the plant can best make protein and sugars and carry out cell functions like growth. This can be near 100 degrees F, as for cucumber, or near 50 degrees F, as for Primula. OK so far?

Now I'm going to share with you a secret. It's often not the temperature specifically that causes the damage; it's the amount of temperature change, the stage of growth, and the speed and duration of that change that determines the amount of damage.

To give you an example, we all know African Violets often develop clear spots on their leaves after being watered with cold water on a sunny day. In my greenhouse class, students who watered their violets with well water at 7:00 am had no spotting! Those that watered with well water at 3:00 pm had serious spotting. What gives? It's all about the cell system!

This is a hybrid landscape Hydrangea leaf 10 days after outdoor temperatures dropped to 35 in Athens, GA. There was no frost, but the new, expanding leaves suffered none the less.

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Effects of Rapid Chilling

Plants are an extremely complex set of chemical reactions. Everything from basic cell materials, such as water and nutrients, to proper levels of enzyme activity as well as proper environment need to be in place for the plant to grow well. These processes can adapt to different temperatures regimes, however that process takes time. This may be hours at best, days or more for many plants and up to 6 months for tropical interiorscape plants used to steady tropical environments. The process is called "acclimatization." Therefore, the amount of damage first depends on how rapidly that species can adapt (3). Sound reasonable? Imagine that in order to adapt, the membrane that encases the cells has to change its protein configuration. Leaves may have to change the orientation of the leaf itself or change the orientation of chloroplasts and the photosynthetic apparatus. Consider also the rate of activity of all the processes such as photosynthesis and respiration. Its complex and takes time.

Then there is the effect temperature has on the rate of the biochemical reactions! This is where the problem lies. It's called "Q-10." The Q-10 refers to how a biological reaction responds to a change in temperature within the temperature limits of a plant. Let's use African Violets. They prefer to

A local Oak leaf that is expressing leaf development abnormality due to chill damage. The temperature rapidly dropped from 74 degrees F to 35 degrees F within 4 hours. Even natives have issues you can spot with a trained eye.

grow in temperatures between 56 and 80 degrees F. Get a little bit outside that range and they slow down but survive. All of their metabolic pathways work pretty well in and near that range, but don't work outside of it. Most plants have a Q10 of 2.0. This 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. So far, so good?

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 can't respond quickly enough. When that happens, parts of the system stall, break, stop or cease to exist. Remember those African violets? An African violet sitting on a bench in a 60 degree F greenhouse at 7:00 am is not going to go into shock when watered with 55 degree F hose water. The difference in temperature is very small, hence you see few, if any, chill spots. On the other hand, water an African Violet with 55 degree water when the plants are basking in 90 degree afternoon conditions and that near instant 35 degree F difference (shift) will shut down the chlorophyll and photosynthesis system completely because of Q-10, but it will not stop other activities in the cells that are not as sensitive (2). Cell and chloroplast membranes begin to leak or become unstable because of the fast change. Even Vacuoles that store plant metabolites begin to leak, rupture or become functionless as their proteins chill and the cell physiology spins out of balance (2). 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.

The cell doesn't turn brown, shrivel or even fall off…it just sits there, damaged. If the

Ferns showing chill damage on the lower portion of the frond from a grower allowing tempertaures to drop to 45 degrees to save money during the Spring. Ferns were then taken into a warm greenhouse. Notice the Pinnae development returns to normal as the fern frond continues to develope.

choilling damage affects many leaves on the plant, growth slows to a crawl and death can eventually occur. There's no fix, no amount of nitrogen you can apply, no magic words that can bring that leaf back to normal. Even watering a toasty warm African violet at 3:00 pm on a summer day with 65-70 degree F water can cause spotting. It's all about rate of change. One final note: Cold water below 55 degrees exceeds the cold temperature limits of an African violet plant (1). If your outdoor cistern water drops to 45 degrees in a cold snap, your violets are doomed if you use that water directly, it doesn't matter how cool the greenhouse night temperature was or how early you watered. Just don't do it!

Now apply what we just discussed to root systems, stem vascular tissues, fruit, reproductive tissue and leaves. A native Oak leaf can have serious chill damage when it's leaf is just past the mouse ear stage. At that stage, cell membranes and leaf tissues are thin, expanding rapidly and constantly being built. Change the Q10 beyond their tolerance (about 34 degrees F) and the leaves develop distortions, necrotic areas or may drop off the tree still green! Their cell membranes have lost integrity. Greenhouse crops such as Lantana and Vinca are notorious for not showing physical signs of chill damage from cold water on a warm afternoon. Every grower that has grown them has seen Vinca and Lantana stall, seemingly to just stop growing…for days and day until finally picking back up, usually after a warm spell of several days. 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 the photosynthetic pathway and the effects can last weeks and delay flowering significantly.

Root tissue, especially in bedding plants and vegetable starts can be dramatically affected by rapid shifts in soil tempera-

In rare cases where the leaf has just expanded and is very vulnerable, you can have this kind of cell damage patter.n Valuoles and other organelle membranes have failed whereas cell walls are intact, leaving this pattern of damage. Notice leaf margins are intact, indicating lack of actual freezing.

ture. Mineral uptake by the root is impaired because of the cold effects on the root hair membranes. Deficiencies can occur even thought adequate nutrition is in the soil! A perfect example is pansies appearing 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. Hence award winning landscapers use foliar fed, nitrate-based, quid feed fertility programs in Winter to maintain flowering pansies!

Boston fern is not adapted to large temperature swings. If the night temperature chills rapidly, will develop leaves that twist and their leaflets will be gnarly and out of synchronicity along the stem. This is why Spring -grown ferns can be damaged by energy saving attempts at lowering the heat at night when not enough time is given to adapt to the lower temperatures.

Adaptability is also why we don't see the same damage in the last days of September, when the ferns are on the outdoor balcony. In Spring the fern "starts" or plugs are grown at a steady warm night temperatures, perhaps in Florida or Texas, and then shipped. If the heat-miser grower has a 50 degree F night temperature and those ferns are used to 70 degrees F, there will be distorted leaves for several weeks, until the nights warm up or the plant acclimates. Rarely do Fall "cold fronts" drop the night temperature far below what the Fern is now used to, having been growing outside all summer, and the drop occurs slowly from sundown to sun-up. Hence, we rarely see distortion.

Your carefully grown vegetable starts, once sold to the clientele this year, likely were exposed to chill damaging temperatures. Symptoms can include leaf pitting, leaf discoloration, limp new growth, stem collapse, flower bud or young fruit abortion and even increased disease susceptibility to Alternaria. True, there was no frost perhaps, but temperatures may have hovered in the upper 30's all night, perhaps with wet leaves. If the plants are in warm soil and had been used to 80 degree F days, as was the case this Spring in many places, chill damage was almost inevitable given the shift of 40+ degrees F!

Finally, know that cultivars have huge differences in chill sensitivity. A paper recently published out of the University of Florida IFAS Extension (1) evaluated Spathiphyllum hybrids for sensitivity to chill damage. The word on the street was that Spaths were generally very tolerant. Results from the study showed leaf chill damage by 38 degree F temperatures varied from 2.5% damage up to 100% damage. For Spathiphyllum, a temperate chill to just 38 degrees F caused significant damage to appear within 24 hours. Many cultivars tested had leaves turn black or exhibited large necrotic areas. It never froze, or even got close! So know your cultivars… every plant has a different tolerance.

In summary:

1). Each plant has both hot and cold temperature limits 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 (in minutes under a hose or over hours in an open field or greenhouse). How rapidly that change can occur matters greatly, and the

duration of the shift matters as well. Most tropical and subtropical ornamental crops are sensitive to chilling, period! With woodies, perennials and native species, it depends completely on the species and stage of growth. Some are insensitive, some are sensitive only when in a growth flush or when blooming.

So How Do I Minimize Chill Damage?

1). Use convection tubes when venting cold winter air in a greenhouse to reduce cold air impact.

2). No matter what you've been told, do not drop night temperatures below the tolerance limit for that crop. There is no free lunch.

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 and at 3:00 pm after running the water 5 minutes!!! Water only in the MORNING preferably before you or the sun warms up the greenhouse!!! In addition to reducing chill effects, you will reduce potential for disease.

4). Run HAF fans 24/7 in the winter to reduce the rate of temperature drops by mixing the air from vents or open doors.

5). If you have perpetual problems with cold well water in northern latitudes, buy a water heater and mix the hot water 1/50, or whatever ratio needed to bring it up to about 60 degrees. Your crop production time will speed up by as much as a week or two well worth the cost of a cheap water heater.

Water As Frost Prevention

Citrus growers in Florida will sometimes spray water on the citrus trees to reduce impending damage. As the ice forms, some heat is given off during ice formation, thus ice doesn't penetrate the leaves and fruit tissue. It works OK for thick cuticular 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. You now know why. 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 to do the same. Use of water to prevent freezing predisposes your leaf tissues will rapidly be near 32 degrees. In many (most) ornamental crops, chill damage is guaranteed.

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