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Cold Protection for Nursery Crops[1]

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Winter temperatures are frequently low enough to cause cold injury to tropical, subtropical and occasionally temperate plants that are produced in Florida. This publication provides information for ornamental plant producers regarding symptoms of cold injury, plant adaptation to cold, environmental conditions leading to cold injury and methods to alter the environment to avoid or minimize cold injury.

Cold injury includes damage from temperatures above and below freezing. Many tropical and herbaceous plants do not adapt or harden to withstand freezing temperatures and may be injured by temperatures below 10°C (5°F). Injury caused by low temperatures above freezing is chill injury and damage caused by freezing temperatures is freeze injury.

Cold Injury Symptoms

Cold injury symptoms usually occur after exposure to critically low temperatures, not during the cold exposure. Direct injury is inflicted at a cellular level and the response of plant tissues to this injury is revealed through visual or measurable symptoms. The rate at which these symptoms develop depends upon the severity of the exposure and the environmental parameters after the exposure. Continued cool temperatures and high humidity after an exposure to cold may slow the symptom development, while high light intensity and warm temperatures may accelerate symptom development.

Chilling

Many chilling-injury symptoms are common to other stresses such as drought stress, root rot diseases, phytotoxicity to chemicals, heat stress and light stress. General symptoms of chill injury to plant leaves, stems and fruits are listed below:

1. Surface lesions, pitting, large, sunken areas and discoloration. These symptoms have been reported on several orchids.

2. Water-soaking in tissues results from disruption of cell structure and release of cell solutes into spaces between cells, and is commonly followed by wilting and browning.

3. Internal discoloration (browning) of pulp, pith, and seed.

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4. Accelerated rate of senescence (natural death), but with otherwise normal appearance.

5. Increased susceptibility to attack by fungi and bacteria not commonly found on the plant.

6. Slowed growth, or limited growth flush. This symptom may be difficult to detect without non-chilled plants for comparison or a thorough knowledge of normal growth rate.

Freezing

Symptoms of freeze injury could include desiccation or burning of foliage, water-soaked areas that progress to necrotic spots on leaves, stems or fruit and death of sections of the plant or the entire plant. Close examination of woody plants several days or weeks after freezing may reveal a dead or weakened root system or split bark on stems or branches. Obvious symptoms on plant foliage may not be present until after the plant has been stressed by warm temperatures. A hot, bright day could increase transpirational water loss beyond the ability of injured roots or stem conductive tissue to replace. Subsequent symptoms might include wilting and/or desiccation, as caused by direct drought stress.

Plant Response to Freezing Temperatures

When considering new plant material for use in the landscape or as a possible nursery crop, cold hardiness should be determined. Hardiness indicates a plant's resistance or ability to adjust to cold stress in order to tolerate freezing temperatures.

The timing and degree of cold hardiness is determined by environmental conditions and the genetic makeup of a particular plant. Inherent, genetic potential is the first limiting factor in development of hardiness, with plant species and genotypes within species differing in their tolerance to cold. Most tropical plants fail to develop hardiness regardless of preconditioning environmental conditions. Some species are always killed by freezing while others tolerate temperatures as low as –196°C (-320°F) in midwinter.

The geographic source of a plant plays an important role in the timing of hardiness. Northern plants sensitive to daylength start to cold harden sooner in autumn than southern plants when grown on the same site. Therefore, selection of seed or cutting stock of desired plants from cold hardy genotypes is an important consideration.

Plant reaction to environmental conditions leading to increased cold tolerance is called <u>cold acclimation</u>, and plant reaction to environmental conditions resulting in less tolerance to cold is called <u>cold declamation</u>. Although in more northern climates acclimation occurs primarily in the fall and declamation in the spring, rapid changes in plant cold tolerance occur throughout the fall, winter and spring months in Florida as environmental conditions change rapidly.

Environmental factors, such as daylength, temperature, nutrition, water availability, light intensity and physiological maturity of a plant or plant part are known to play a role in cold acclimation. Once the effect of these environmental factors on cold acclimation is understood, sound cultural practices directed toward increasing cold tolerance can be developed.

Generally, plant growth slows or ceases before cold acclimation begins. Decreasing daylength provides the primary stimulus or trigger for cold acclimation in many plants. Phytochrome, a light-receptive sensory pigment in leaves and bark, detects decreasing daylengths of autumn and initiates biochemical and physiological changes that slow vegetative growth and increase cold acclimation. Plants that react primarily to daylength slow growth at approximately the same time each year, regardless of temperatures. Temperature is the primary stimulus for cold acclimation in some subtropical plants such as citrus. However, in most plants there is an interaction between photoperiod and temperature on plant growth and development, and the most rapid cold acclimation is produced by short photoperiods and low temperatures.

Plants should withstand cold best if fertilized with a balanced ratio of plant nutrients that produce optimum growth (Pellet and Carter), but the rate of fertilization should be reduced slightly in fall and winter to reflect the lower nutrient requirement during the cold months. Plants under severe nutrient deficiencies or plants receiving nutrients at near toxic levels do not withstand cold or recover from cold injury as well as plants with properly balanced nutrition.

Moderate drought stress can result in increased cold tolerance in some plants by slowing growth and initiating dormancy. Many plants native to the dry plains respond to this treatment because in nature the plants are commonly subjected to dry conditions before the onset of winter. Although water stress may increase cold tolerance in some plants, such stress may result in an unacceptable decrease in quality of plants such as azaleas.

The maximum cold tolerance level is seldom reached in Florida, even with temperate plants, because of the loss of hardiness during extended warm periods in winter months. Plant metabolic activity slows during extended cold periods, but a period of warm temperatures can stimulate rapid declamation. Temperature seems to be the primary environmental factor controlling declamation and plants can reacclimate if a subsequent slow temperature drop occurs. A rapid temperature drop following a warm period, a common event in Florida, may produce injury and death to plants.

Evaluation of cold hardiness is further complicated because different tissues and organs of the same plant may display varying degrees of hardiness. Flower buds are often damaged by freezes while vegetative buds or stem tissues are uninjured. Plants grown for their floral display may be hardy, but if their flower buds are killed every year, they will be unsatisfactory for landscape use. Leaves of broad-leaved evergreens may be injured by cold yet the stems remain unharmed. Root tissues are less resistant to freezing injury than stem tissues, with young roots being more sensitive to cold than mature roots. Stems and leaves of Pyracantha coccinea 'Lalandii' acclimated to –26°C (-15°F), and mature roots to –17°C (1°F), while young roots failed to survive below -50C (23°F) (Waist and Steponkus). Lack of old resistance in roots is not usually a problem in field production or in the Florida landscape, however, it may be the limiting factor to winter survival of containerized plants when prolonged freezing temperatures occur.

Plants that survive freezing temperatures must either avoid or tolerate the formation of ice in their tissues. The primary mechanism by which plants avoid freezing is supercooling. Supercooling occurs when the plant's temperature drops below its freezing point without ice formation. Even pure water will supercool. The lowest subfreezing temperature recorded before ice formation is the supercooling point. Unfortunately this point is not a constant value but varies for repeated tests on the same solution. Under field conditions supercooling generally allows nonacclimated plants to avoid freezing when temperatures in the -1 to –3°C (31 to 26°F) range occur.

Cold-resistant plants tolerate water freezing in their tissues as long as the ice crystals form between cells (extracellular freezing) and not inside them (intracellular freezing). Extracellular ice formation is the type of freezing encountered in nature and is tolerated by hardy plants in their cold-acclimated state. Intracellular freezing disrupts the cell and is always fatal. Generally, freezing rates in nature are too slow to allow intracellular freezing. Cooling rates of 2°C per minute or faster are required for intracellular freezing, and slower cooling allows sufficient time for water to move through the surrounding membrane and form ice crystals in extracellular spaces. Thus at the cellular level, the requirements for freezing resistance in any hardy plant are the avoidance of intracellular freezing and the tolerance of extracellular freezing.

Principles of Heat Transfer

Heat loss by plants involves heat transfer which should be understood before formulating and evaluating cold protection methods. Heat may be transferred by conduction, convection or radiation.

Convection

Convection is the process of heat transfer within a fluid or air that results in mass motion of molecules in that fluid or air. Heat is transferred from air at the soil surface to air above the earth by convection. Air becomes lighter when heated and rises to be replaced by heavier, cooler air. This mass motion of air is called convective mixing and explains why air just above the earth's surface does not become extremely hot on a sunny, summer day.

Radiation

Radiation is the process of heat transfer from one object to another without the aid of a transfer medium. The sun's rays heat the earth's surface and can burn human skin by radiant heat transfer. The surfaces in a greenhouse are warmed by absorption of short wave solar radiation. These surfaces reradiate heat to the air above them as long wave or infrared radiation.

Environmental Conditions Leading to Cold Injury

Cold conditions in Florida are a result of cold air masses moving down through more northern states and pushing into Florida. Temperatures associated with these fronts depend upon where the pressure systems originate and the rate at which they move into Florida. Environmental conditions created by these cold fronts can be categorized into one of two general types: moist air with considerable cloud cover or dry air and clear skies. Windy conditions can accompany either of these conditions, and wind is an important consideration in developing plant-protection strategies. Daily temperature fluctuations are greatest when clear skies exist. Solar radiation warms the earth's surface during the day and air temperatures of 16 to 21°C (60 to 70°F) are common even though the minimum temperatures at night may be less than –1°C (30°F). This large fluctuation is primarily due to radiation cooling.

Radiational cooling occurs primarily at night when the heat absorbed by the earth's surface during the day is reradiated into the atmosphere. Air at or near the soil surface is warmest during day and coldest during night under such conditions. Heat lost from surfaces by radiational cooling moves away from the earth's surface by convective mixing. The soil continues to lose heat until it is colder than the air just above it; then the soil absorbs heat from the air. The existing condition is a cold air layer near the earth's surface with a rapidly cooling soil surface. The warmest air may be from a few feet to one hundred feet above the soil surface. Plant leaves close to the ground may sustain freeze injury even through the temperature a few feet above the leaves is above their freezing point. This condition is called a “temperature inversion" because it is an inversion of normal daytime conditions where the warmer air is near the ground.

Moist air and cloud cover reduce the fluctuation of daily air temperatures. Cloud cover reduces the amount of solar radiation reaching the earth's surface during the day, and heat radiating from surfaces on a calm night is absorbed by clouds and reradiated back to the earth's surface. The primary cooling process of plants and other objects during cloudy, calm, cold weather is conduction of heat from the leaf to the colder air surrounding it. Leaf temperature generally is not lower than the air temperature in these conditions.

Wind increases the rate of temperature drop. A 5- to 10-mph wind on a cold, cloudy night constantly replaces the warmer air on leaf surfaces with cold air, and this accelerates the rate of heat loss from the leaf. A temperature gradient will develop between the leaf and the air if the air is calm and the rate of heat loss from the leaf would be reduced slightly. Wind on a clear night prevents or reduces the formation of an inversion layer by mixing the warmer air above the crop with colder air at the crop surface, thus slowing the rate of leaf temperature drop.

The lowest temperatures occur in Florida when cold, dry (clear skies) air masses move rapidly across the United States and into Florida. Generally, as such a cold front moves from north Florida to south Florida, the temperature of the air mass increases, but the amount of temperature increase depends upon how fast the front is moving. Clear skies at night greatly increase the chance of crop injury by allowing considerable radiational heat loss from the crop environment.

The terms frost injury and freeze injury are often confused. The injury mechanism in both is the freezing of cellular water, but freeze injury can take place even if frost is not present. Frost occurs when the dewpoint of the air (the temperature at which air is saturated with water) is reached at freezing temperatures. Air can hold less water vapor as it gets colder. When the dew point occurs at freezing temperatures, the water vapor in the air changes to ice crystals on exposed surfaces. When the air contains a lot of moisture, the dew point may be reached before freezing temperatures occur and water vapor will condense as a liquid on exposed surfaces. Dew may freeze after it has condensed on leaf surfaces if the air temperature drops below freezing, but this type of ice formation is less damaging to plants.

When the humidity is very low, freeze injury can occur without frost. Freezes without frost are often called "black frosts."

Measuring Environmental Conditions

Proper measurement of environmental conditions is essential for predicting or assessing plant response and for optimum management of plant protection systems. Temperature is the most important environmental parameter to be measured by the nursery manager. However, temperature measurements related to relative humidity and wind speed and direction can provide the manager with more insight into current and expected conditions.

Relative humidity is the quantity of water vapor present in the atmosphere, expressed as a percentage of the quantity which would saturate the air at the same temperature. Relative humidity helps to determine how rapidly temperatures drop. It also affects plant response to cold temperatures and influences how well specific protection systems work. Air with a high relative humidity will resist temperature change more than dry air, and plant water lost to desiccating winds will be lessened by high relative humidity. Relative humidity sensors and recorders are available in a wide range of prices and accuracies. One practical way of measuring relative humidity at a given temperature is with a wet-bulb thermometer. A wet-bulb thermometer has a bulb covered with a moist muslin bag, thus lowering the measured temperature by loss of latent heat through evaporation. The lower the wet bulb temperature compared to the dry bulb temperature, the lower the relative humidity.

Care should be taken to purchase high quality thermometers which should be routinely calibrated in an ice water bath. Electronic sensors such as thermocouples and thermisters can be purchased or made to sense a temperature at a particular point. Microprocessors are available that can be programmed to scan a large number of temperature sensors at predetermined time intervals and record the temperatures.

Methods Used for Cold Protection

Water Used for Cold Protection

The unique physical properties of water as a vapor, liquid or solid make it a primary factor in plant protection from freezing or chilling temperatures. As water cools at temperatures above freezing, "sensible" heat is released. Actually, 1000 calories of heat energy are released as 1 liter of water is cooled from 3°C to 2°C (8.3 BTUs /gallon/°F). A BTU, British Thermal Unit, is defined as the heat required to raise the temperature of 1 pound of water 1°F or to raise 816 grams of water 1°C. As water cools from 16°C (60°F) to a liquid at 0°C (32°F) 16 kcal per liter (232 BTU's per gallon) of water are released into the surrounding environment. Fogging, flooding and sprinkling (at temperatures above freezing) use the sensible heat in water to moderate temperature drop in the nursery.

When water changes from a liquid to solid state (ice), a tremendous amount of energy is released. This energy is called the "heat of fusion" and is equal to 80 kcal per liter or 1200 BTU's per gallon. Sprinkling when air temperatures are below or approaching 0°C (32F) is sometimes called icing and uses the heat of fusion to provide cold protection for plants.

Sprinkling

Sprinkling for cold protection is becoming increasingly popular in Florida nurseries. It can be used to moderate temperatures above freezing because of sensible heat in water and can maintain plant leaf temperature at 1 to 2°C degrees or more. Sprinkling should continue until after thawing or the wet bulb temperature rises above freezing especially if windy, dry conditions prevail. Evaporative cooling occurs because heat energy is lost to the atmosphere as water changes from a liquid to a vapor. Do not rely on a household window thermometer to monitor leaf and air temperatures.

The water must be delivered uniformly with allowances for changes in wind velocities and direction. Wind adversely affects the sprinkler distribution pattern and causes the heat from the heat of fusion to be lost by evaporation. This means that up to seven times the amount of water used for a freeze on a calm night must be applied to compensate for heat loss due to evaporation and conduction when a 5- to 10-mph wind exists.

The greatest disadvantage of sprinkling is breakage of plant limbs due to ice weight. Easily broken container plants may be placed on their sides and iced to prevent breakage, but should be placed upright as soon as possible after the freeze.

Sprinkling for freeze protection can be used effectively in Florida. Plants do not have to be repositioned, and there are no structures to erect, therefore the reduced labor requirements for sprinkling is an advantage. However, frequent sprinkling may leach nutrients and/or cause waterlogged soils or container media which may result in plant stunting or death. The large amount of water required for this practice could be a limiting factor in some areas of Florida.

Water applied to aisles of shade structures or greenhouses increases the moisture content of the air and soil surrounding the plants (increases wet-bulb temperatures), thus slowing the rate of temperature drop. The water absorbs heat during the day which is released slowly at night. The water should be applied in late afternoon of a warm day. Sides of adequately constructed shade houses can be covered with ice by sprinkling on freezing nights to reduce the effect of wind.

Fog

Fog also retards the loss of heat from soil and plant surfaces to the atmosphere. Natural fogs create a barrier to radiant heat loss much like clouds, although their effectiveness varies with the size of the suspended water particles. Fog can provide up to 4°C (8°F) of protection outdoors during radiational cooling. Applying ground water with an average temperature of 21°C (70°F) to a shade house or greenhouse can create a ground fog if the ground surface is several degrees cooler than the water. This applied water adds heat to the plant environment and/or buffers temperature change by increased humidity. Fogging is most effective in an enclosed structure such as a greenhouse or partially enclosed structure such as a saran house but must be uniformly distributed. Temperatures can be elevated as much as 5°C (9°F) in these unheated structures. High pressure, low volume systems are the best means available to create a uniform fog. A low volume system dramatically reduces water requirements compared to sprinkling.

Air Movement for Cold Protection

Wind machines have been used for many years in citrus and vegetable industries and recently in the ornamental industry as a means of cold protection. Wind machines are only effective in the advent of radiational freezes characterized by winds less than 5 miles per hour.

Denser cold air settles in low areas resulting in temperature strata with warm air above the cold. Wind movement can disturb this inversion existing on calm nights. This forced air movement will mix the cold and warm air resulting in warmer air surrounding the plant. Air movement also helps distribute and circulate heat added by orchard heaters or other sources.

Cold Protection Structures

Structures for cold protection are used to prevent plant desiccation caused by winds associated with severe freezes, to trap heat present and to contain supplied heat energy. They should be constructed to withstand high winds and minimize heat loss. These structures are expensive because of construction materials and required labor for movement of plants in and out as the conditions or seasons change.

Florida nursery operators should analyze nursery production systems for each plant species, the risk of cold damage and the projected dollar return before investing in structures for cold protection. Certain high value crops warrant structures specifically for cod protection, but in other cases, dual purpose structures should be considered. A structure used for shading in summer often can be used for cold protection during winter.

Structures can be constructed of wood, galvanized pipe, conduit, PVC pipe, or concrete reinforcing rods and cost will be the overriding factor in determining which to use. Sizes of structures depend on size of plants to be protected, growing bed width and length, and the production system used. Detailed plans for various greenhouses and cold frame structures can be obtained from the Extension Agricultural Engineer through your local cooperative extension agent.

A common winter protection structure is the quonset type constructed of bent galvanized pipe. Half-inch pipe joints are used for bows which are placed inside larger pipe studs that protrude 15 cm (6 inches) from the ground. This results in a house 4.3 meters (14 feet) wide and 1.8 meters (6 feet) tall. The bows are usually 61 cm (2 feet) apart and the house is usually long enough to accommodate common-size polyethylene. One purlin down the center is adequate for support. Similar construction with PVC pipe bows also has become popular due to reduced costs of PVC pipe. The house should be oriented in a north-south direction to distribute the light uniformly within the structure. A clear polyethylene covering (4 to 6 mil) is usually pulled over the ends and secured along the sides. A door at one or both ends facilitates entry. Venting may be done by raising the plastic on the side opposite prevailing winds and closing during cold weather.

Frames for such permanent structures are usually built on a portion of the container production area and plants from areas adjacent to the quonsets are crowded into these structures to reduce the number of houses needed. The irrigation system for the container production area is usually not flexible enough to use to irrigate plants enclosed in these quonsets and expensive hand watering may be required.

One may elect to construct small, lightweight, portable structures which can be placed over beds of cold-sensitive plants during cold weather and removed during warm weather. Such portable structures may be small quonsets constructed of conduit, PVC pipe or concrete reinforcing rods covered with concrete reinforcing wire for support. They should be wide enough to span a bed 1.8 to 3.0 meters (6 to 10 feet) long. Quonsets made to stack on top of each other will facilitate storage. Polyethylene coverings can be attached to wooden strips at the bottom of each side. A small piece of plastic may be secured over ends of the structures and opened during the day for ventilation. Portable quonsets have definite advantages to the nonportable galvanized pipe structures since plants are not repositioned and the structure may be removed for watering.

Winter temperatures in Florida are not consistently low enough to warrant placing plants on their sides in structures and covering with Styrofoam™ or polyethylene material for the entire season. Nursery operators might consider placing high-value container plants on their sides in the event of a severe freeze. The plants may then be covered with 1 or 2 mil of polyethylene, Styrofoam™ or other insulating material supported just above the plants so the cover is not in direct contact with the foliage. The insulating material should be removed and the plants placed upright after the freeze.

Shade structures are most effective in providing protection during cold weather with little air movement. Saran structures may raise the ambient temperature under them 1 to 2°C (2 to 4°F) by reradiated heat radiating from the ground and objects within the structure. Lath houses are less efficient than saran structures at reradiating heat, but both provide some cold protection. Sides of shade structures may be covered with water during freezing conditions since the ice forms a windbreak. Care should be taken that ice loads do not crush the structure. Some shade structures are designed so they can be covered with polyethylene film during winter months or when cold weather is expected.

Plants may be placed in cold frames for protection from rapid temperature fluctuations. Small plants, such as liners, can be set upright in the frame while larger plants (1 gal. etc.) may be placed on their side. Placing larger plants in the frame is an expensive operation, and one should contemplate placing the plants on their sides and covering in the field rather than transporting to a cold frame. In either case, the plants should be placed upright as soon as cold weather passes. Frames may be economical for protection of liners which were propagated and/or held in the frame through the winter. Cold frames may be covered with polyethylene, Styrofoam™ or other insulating materials placed over the plants to trap radiant heat. Polyethylene or other light transmitting covers with a southern exposure permit solar radiation to warm the structure. The frame covering should be removed on warm days to prevent excessive heat build up.

Supplementary Heat

Air temperatures inside unheated quonsets made of a single layer of plastic are usually about 3°C (5°F) warmer than outside air on a cold night. This small temperature differential can be critical to the survival of many plants, however, supplemental heat ensures that plant environment temperatures are above critical levels. Adding heat to an enclosed structure is more feasible than heating an outside growing area with orchard heaters, but energy costs may prohibit the heating of any woody ornamental growing area. If outside heating is used, it should be combined in combination with other protection techniques such as wind movement, fog or some barrier created to reduce radiant heat loss. The decision to add supplemental heat must be based on crop value and rate of return on investment.

Heat sources for structures include solar radiation, well water and boilers fired by oil, gas or wood. Solar heating systems, warm water units and unheated well water circulation offer the greatest potential for Florida woody ornamental growers. Nursery operators should consult their Water Management District personnel before installing unheated well water circulators. Several passive solar heating designs are available that collect the sun's rays and store this heat energy in some medium like stone or water. The heat collected during the day is then circulated in the structure at night.

Circulation of warm water (43 to 54°C, 110 to 130°F), not hot water, in enclosed growing and/or storage areas has gained popularity in recent years. Warm water is more economical than forced-air heat to keep plant environments above a critical minimum temperature. This water often is circulated through PVC pipe installed in some material like sand or concrete under plant containers.

Well water temperatures in Florida during winter months range from 20 to 24°C (68 to 75°F). A system has been designed and tested at the Agricultural Research Center in Monticello, Florida that circulates unheated well water through PVC pipe in a propagation cold frame. This system kept the minimum cold frame soil temperature above 12°C (54°F) and the minimum air temperature above 8°C (46°F) while outside temperatures were below –7°C (20°F) for several hours. Minimum soil and air temperatures in cold frames without this water circulation system were 4°C (40°F) for the same time period.

The decision to add heat to the plant growing environment must be based on economics. Costs and returns for a given heating system, structure and crop plant must be known or estimated before a system is constructed or an existing system is used.

Treatment of Plants After Cold Stress

The environment to which plants are subjected after cold stress affects the degree of injury and rate of symptom development. Importance of post-exposure environment varies with the severity of cold stress. Plants exposed to temperatures below their cold tolerance level will not recover, however, damage to plants exposed to near critical temperatures may be influenced by post-stress handling.

Intense light, low humidity and high temperatures following chilling of some tropical plants result in increased water loss through transpiration. Extreme water stress can develop if the chill exposure has disrupted water absorption, temporarily or permanently.

Root systems of plants in field production are seldom frozen in Florida, but roots of container-grown plants can be frozen for several consecutive hours. Clear skies are common when extremely low temperatures occur in Florida. Sunny conditions on mornings after night freezes can result in rapid transpiration (water vapor loss) as leaves are warmed, but the soil/root mass may be frozen and unable to provide ample water to leaves, resulting in excessive water stress and leaf desiccation. Symptoms may not occur for several days and may be manifest as marginal leaf scorch or overall browning. Watering container-grown plants can thaw the growing medium/root mass and allow water absorption and transport to the leaves. Excessive water, however, can leach nutrients and cause root injury by waterlogging the growing medium.

Cold injury to roots may not be evident until spring when plants are stressed by high temperatures. Failure to initiate a spring growth flush may be the only visual symptom of winter injury and little can be done to minimize the effect of winter injury at this time. Weakened or injured plants are more susceptible to disease attack, so growers should increase frequency of inspection and implement a preventative fungicide program if justified. Increased shade may also reduce heat or water stress during recovery periods. Justification of such efforts should be determined on an economic basis.

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