The Big Chill: Cold Temperature Effects on Plants and How to Avoid Damage

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Talk Outline

- Cold Hardiness
  - ✓ Hardiness zone maps
  - ✓ Climate change
- Cold Acclimation and Dormancy
- Provenance
- Winter Damage
  - ✓ Types
  - ✓ Causes
  - ✓ Prevention
  - ✓ Treatment

Cold Hardiness

- ✓ Ability to survive the freezing of water in plant tissues
- ✓ Measure of average, annual, minimum winter temperatures: long term records
- ✓ Does not report temperature extremes, annual rainfall, drought, summer temperature extremes, night temperatures
- ✓ Plants hardy to zone 5: Wisconsin vs. Nebraska vs. western Montana
- ✓ Plant marginally hardy plants in sheltered areas

USDA Cold Hardiness Zone Map

- ✓ Zones further divided up into two subzones of either "a" or "b"
- ✓ Separated by 5ºF increments
- ✓ Subzone "a": colder part of a hardiness zone
- ✓ Subzone "b": warmer part of a hardiness zone
- ✓ Zone 4: -30 to -20ºF
  - Zone 4a: -30 to -25ºF
  - Zone 4b: -25 to -20ºF

Cold Hardiness

- ✓ Subdivision of zones critical for estimating cold hardiness
- ✓ Hardiness can vary based on only 5ºF (i.e. maples)
- ✓ Choose colder hardiness zone plants ("a" zone)
- ✓ Many plant catalogs and books are incorrect and over estimate hardiness zones!
- ✓ Buy local if you can; start with smaller plants

Cold Hardiness

- Hardiness varies by species genetics, stage of growth, age, condition, and plant organ or tissue
  - ✓ Roots less cold hardy than vegetative portion, but continue growth at lower temps.
  - ✓ Flower buds often less cold hardy than vegetative buds
- Gradual hardening of plant tissues If temps. drops quickly rather than slowly: more injury susceptible

Seasonal Cold Acclimation Process

- First stage: Induced by shorter days and non-freezing, cooler temps. in fall
  - ✓ Internal calcium signals acclimation process
  - ✓ ABA moves from leaf to stem phloem
  - ✓ Cellular and metabolic changes
  - ✓ Organic compounds stored, concentrates solutes
    - ✓ Sugars (more for herbaceous plants), lipids, amino acids, proteins (more for woody plants)

Seasonal Cold Acclimation Process

- First stage: Induced by shorter days and non-freezing, cooler temps. in fall
  - ✓ Lipids and proteins synthesized or change structure
  - ✓ Freezing point inside cell decreases: super-cooling, prevents ice crystal formation
  - ✓ Cells survive temperatures well below 32ºF, but not fully hardened

Seasonal Cold Acclimation Process

- Second stage:
  - ✓ Induced by lower temps, particularly < 32ºF
  - ✓ Continued slow cooling for a month or more at temps < 14ºF
  - ✓ When fully hardened, cells tolerate exposure to very low temps.
  - ✓ Withstand temps. -10 to 20ºF
  - ✓ Plant enter endo-dormancy (deep)

Cold Acclimation in Plants

- Extracellular Freezing
  - ✓ Fatty acid desaturation in plasma membrane
    - Permeability of plasma membrane changes
    - Membrane more fluid, does not solidify, avoids damage at low temperatures
  - ✓ Water leaks from inside the cell to outside in intercellular spaces
    - Cell dehydrates and shrinks; no ice inside cell
  - ✓ Water crystalizes gradually between cells and outside xylem vessels, slowly
    - If too quick, ice crystals puncture and destroy cell contents or ice crystals form within cell, lethal

Endo-Dormancy

- Endo-dormancy: buds will not grow even with favorable environmental conditions
  - ✓ Number of chilling hours spent above freezing (35-45°F)
  - ✓ Chilling requirement accumulation: 500-1500 hours (4-8 weeks)
  - ✓ Warmer for subtropical species
  - ✓ Hours < 32°F no effect on chilling hours, but acclimates further to very cold temps.
  - ✓ Chilling hour requirements and cold hardiness independent of each other

Endo-Dormancy

- Develops within each bud or seed of temperate plants
  - ✓ Keeps plants dormant even if short, warming temps.
- Maximum dormancy in Dec.-Jan. gradually decreases in late winter (March)
- Without adequate chilling, lack of leaf out or very slow, or may die
- More damage with warming of planet, can plants adapt?

Final Stage: Eco-Dormancy

- Eco-dormancy: chilling hour requirement met, no longer dormant, just "quiescent"
  - ✓ Growth depends on heat unit accumulation
  - ✓ Grows once temperatures adequate
  - ✓ Native plants stay in quiescent state longer than some exotics, photoperiod response

Final Stage: Eco-Dormancy

- Eco-dormancy:
  - ✓ Plants lose enhanced ability to re-acclimate to very cold temps.
    - If warm temps. in winter: lose cold acclimation
    - Becomes cold injury susceptible
    - Can reacquire deeper cold hardiness, but slower process over several days to week

Cold Acclimation in Plants

- Deacclimation of plants
  - ✓ Reverse process of acclimation
  - ✓ Occurs slowly
  - ✓ Once growth resumes in spring, looses hardiness (-31ºF hardy now only 14ºF)
  - ✓ Ice crystals can form with very cold temps., cells dehydrate further or burst

Types of Cold Temperature Injury

1. Cold temperature injury
   - ✓ Winter kill of buds or twigs, dieback
   - ✓ Root injury and death
2. Frost damage: fall and early spring
3. Leaf tatters
4. Sunscald, frost crack, bark splitting
5. Winter burn
6. Frost heaving of new plants
7. Snow and ice damage
8. Deicing salt injury
9. Animal damage

Cold Temperature Injury

- Causes:
  1) Non-hardy or marginally hardy plants
  2) Very cold snap in winter
     - Temps. fall far below U.S.D.A. Cold Hardiness Zones limit
     - Longer durations: worse damage, Winter 2019
     - No snow cover, deeper frost line, roots damaged
     - Clear nights, calm winds: more heat radiated to atmosphere
     - Temps. before a severe freeze determine extent of damage
     - Stressed trees more susceptible to damage

Cold Temperature Injury

- Causes:
  3) Warm, late fall followed by rapid Dec. freeze
  4) Very cold in mid fall before plants hardened off fully
     - Halloween 2019, 4" snow, very cold temps.
  5) Warmer winter temps. followed by very cold
     - Plants gain/lose cold hardiness with larger temp. fluctuations
     - Very damaging to plants
     - Damage not evident until next spring
     - Lost fruit and nursery crops: apples, grapes, etc.

Cold Temperature Injury

- **Causes:**
  6) **Early spring freezes**
     - Most common winter injury with spring freezes
     - Mid to late April to early May
     - Once growth begins, bud/shoot cold tolerance depends on stage of development
     - Plant de-hardened, lost severe cold acclimation
     - Ruined fruit crops: apples, grapes, etc.
     - Can resume normal vegetative growth
     - May need corrective pruning

Cold Temperature Injury

- **Symptoms:**
  - ✓ Flower bud kill or severely damaged: no fruit
  - ✓ No bud break, vegetative buds killed
  - ✓ Spring shoots/leaves wilt and die: no water uptake
  - ✓ Roots less resistant to freezing than stems
    - ✓ Raised planters/containers: no insulation
    - ✓ Lack of snow cover, deeper frost line penetration
    - ✓ Dry, sandy soil more susceptible than moist soil

Cold Temperature Injury

- **Symptoms:**
  - ✓ Shoot dieback
  - ✓ Slower growth next year
  - ✓ Susceptible to pests, especially root rot
  - ✓ Branch and trunk cracks: cambial death
  - ✓ Entire plant dead above snow line
  - ✓ Damage varies by species/cultivar, location

Provenance

- **Provenance:**
  - ✓ Geographic origin of seed collected
  - ✓ Where in the country, state, county, etc. did you collect the seed, i.e. latitude and longitude
- **Plant populations evolve, become adapted to environmental conditions at that site**
  - ✓ May look different or be less/more cold hardy

Provenance

- **Seeds collected in one locality may produce plants inappropriate to another area**
  - ✓ Warm climate collected seeds planted in northern U.S.
    - Seedlings may not stop growing early enough in fall, frost damage or death, lack cold hardiness, break bud too early in spring

Provenance

- **Seeds collected in one locality may produce plants inappropriate to another area**
  - ✓ Cold climate or high elevation collected seeds planted in southern U.S.
    - Reduced growth of seedlings, differences in photoperiod response, does not break dormancy, lack of heat tolerance

Provenance

- ✓ Differences in morphology, physiology, adaptation to climate and soil, resistance to pests, cold hardiness, heat tolerance, length of dormancy required to break buds
- ✓ Crucial for native species, seed propagated with a large, native, geographic range
- ✓ Important for native AND exotic species
- ✓ Collect from northern seed source to ensure cold hardiness
- ✓ But what about climate change?
- ✓ Should we select more southern provenances for breeding?

Late Frost Injury

- As little as 2°F can make a huge difference in plant tissue survival
- Large bodies of water (Great Lakes) help moderate temperatures
  - ✓ Slow, gradual increase in temperatures in spring, cooler in summer due to winds, slightly warmer in fall and winter
- Air passing over frozen water is cooled, delaying bud break in spring
- Air passing over open water is warmed, helps prevent late frost injury

Late Frost Injury

- Sky is clear, low humidity, calm during the night
- Very low temps occur in fall or late spring
- Tender new leaves appear water-soaked, may turn black
- Some tissue turn brown, wilt, shrivel up

Late Frost Injury

- March, 2011, unseasonably warm temps (70-80ºF) followed by normal April with freezing temps.
  - ✓ New growth on exotics killed by freeze
  - ✓ Flowers killed and new leaves
  - ✓ Opening flower buds killed: cherries, magnolias, serviceberry
  - ✓ Happened again in May: hydrangeas
  - ✓ Plants rely on stored energy to reflush leaves from lateral buds, no flowers

Leaf Tatters

- Late spring frosts as buds expand
- May cause damage to developing leaves
- Injured leaves appear sheared, jagged, distorted, lacy in texture and may brown with curled edges
- Symptoms apparent a day or two after frost
- Winds dry out and tear or shred leaves further
- Often seen on oaks
- Trees growing in low areas or frost pockets are most susceptible
- Treatments are not needed, will grow out of it

Sunscald Injury

- Interaction of temperature and light in winter; alternate freezing/thawing
- Sunny, winter days heat trunk tissue on south, west or S.W. side
- Trunk temp. > air temp. by up to 20ºF during day
- Sun sets, trunk temp. drops fast
- Shrinkage of bark tissue; vertical cracks

Sunscald Injury

- Ice crystals expand, rupture internal cells and tissue; tissue death
- Thin barked and newly planted trees, trees with trunk or root injury, borers and especially drought stressed trees all contribute to sunscald injury (Roppolo and Miller, 2001)

Sunscald Injury

- Sunscald Symptoms:
  - ✓ Damage late winter-early spring
  - ✓ Bark separates from wood
  - ✓ Cambium, phloem, xylem damaged
  - ✓ Inner bark turns brown, splits
  - ✓ Sunken, elongated area, dry, discolored, cracked, dead, peeling bark
  - ✓ May or may not crack open
  - ✓ Wounds invaded by canker fungi, wood decay; girdles
  - ✓ Sickly looking trees, stunted

Sunscald Injury

- Sunscald Symptoms:
  - ✓ Newly planted, young and thin-barked trees show more damage
    - ✓ Mountainash, lindens, tuliptree, honeylocust, cherries, plums, birches, crabapples, pears, young maples, musclewood, magnolias, beech, horsechestnuts and buckeyes, London planetree, elms, willows
  - ✓ Older trees less susceptible
  - ✓ Borers near sunscald areas
  - ✓ Tree decline over several years

Frost Crack Symptoms

- Outer layer of wood contracts more rapidly than inner wood
- Longitudinal trunk cracks in the bark and wood
- Parallel to grain extending to center of trunk
- Trees 6-18"dbh affected more than smaller or larger trees
- Likely appears yearly
- May occur with sunscald

Sunscald and Frost Cracks

- Prevention:
  - ✓ Maintain lower branches on young trees for several years; shades trunk, keeps cooler
  - ✓ Lawn mower/trimmer injury exposes basal bark; see more damage; collar and root injury
  - ✓ Remove double leaders, narrow branch crotches and included bark
  - ✓ Avoid flush cuts when pruning

Sunscald and Frost Cracks

- Prevention:
  - ✓ Southwest side of trunk in nursery should face southwest in landscape
  - ✓ Do not bury the root flare; basal and root injury, collar rot; further bark/trunk injury, cracks
  - ✓ Mulch 3-4" around tree, avoid any touching trunk
  - ✓ Orchard trees with white paint, reflects sunlight
  - ✓ Water trees during drought and in fall and newly planted trees; less root injury

Sunscald and Frost Cracks

- **Prevention:**
  - ✓ **Tree wrap did NOT reduce incidence of frost cracks: no reflective quality, bark still heats up**
    - ✓ Wrap needs removal in early spring, left on too long, girdles (spiral, plastic wraps)
    - ✓ Heats up underneath, nice place for insects
    - ✓ Keeps area underneath too wet, rot and fungi develop
    - ✓ Use of loose, white, plastic guards with holes better, reflects sunlight; avoid black plastic
    - ✓ Guards placed around tree base helps prevent lawn mowers, string trimmers and animal damage
    - ✓ Use tree guards in late fall, remove after last, spring frost

Sunscald and Frost Cracks

- **Prevention:**
  - ✓ **Tree wrap did NOT reduce incidence of frost cracks: no reflective quality, bark still heats up**
  - ✓ **Wraps do not prevent borer injury (Appleton and French, 1992)**
  - ✓ **Repair area to help wound closure**
    - ✓ Remove dead bark/jagged edges back to live tissue with clean, sharp knife, round off sharp corners
    - ✓ Do NOT use tree paint or wound compound

Winter Burn

- Interaction of temperature and wind in winter
- Sunny, windy days, frozen ground, temps. > 32ºF
- Form of drought stress
- Water absorption by roots cannot replace water loss by leaves, buds and stems
- Trunk unable to transport water to foliage
- Broad-leaved and needle-leaved evergreens

Winter Burn

- **Winter Burn Symptoms:**
  - ✓ Dry leaves and needles
  - ✓ Leaf curl and wilting
  - ✓ Browning of leaf margins on broadleaves
  - ✓ Brown or reddish-brown needles, scale, awl-like
  - ✓ Severe browning and death of entire plant
  - ✓ If snow present, no damage below snow line
  - ✓ Damage evident in spring
  - ✓ Buds not effected

Winter Burn

- **Degree of winter burn can vary by:**
  - ✓ Species and cultivar
  - ✓ Plant part, age of plant, plant health
  - ✓ Years since transplanting
  - ✓ Soil type and moisture content going into winter
  - ✓ Depth of frozen soil/frost line
  - ✓ Snow cover
  - ✓ Wind velocity and sun exposure
  - ✓ Timing, duration and severity of winter temps.
  - ✓ Very cold temperatures in fall before fully acclimated or late spring after dehardening
  - ✓ Excessive road salt accumulation

Winter Burn: 2014

- **Susceptible plants:**
  - ✓ Boxwood and yews
  - ✓ Globe arborvitaes and giant arborvitae (*Thuja plicata*)
  - ✓ Upright and shrub junipers
  - ✓ Falsecypress (*Chamaecyparis* spp.)
  - ✓ Weeping Nootka falsecypress (*Cupressus nootkatensis* 'Pendula'
  - ✓ Scots, Austrian, Japanese white, 'Vanderwolf's Pyramid' limber pines
  - ✓ Concolor and balsam firs, Douglas-fir
  - ✓ Dwarf Alberta spruce, Oriental spruce, dwarf cultivars of Norway spruce
  - ✓ Eastern hemlock and cultivars
  - ✓ All broad-leaved evergreens including rhododendrons

Winter Burn: 2014

- Winter burn resistant plants:
  - ✓ Upright and newer cultivars of eastern white-cedar except 'Pyramidalis'
  - ✓ 'Everlow' and 'Tauntonii' yews
  - ✓ Swiss stone pine (*Pinus cembra*)
  - ✓ Balkan pine (*Pinus peuce*)
  - ✓ Eastern white pine (*Pinus strobus*)
  - ✓ Norway and white spruce (not dwarf cultivars)
  - ✓ Groundcover junipers (under snow)
  - ✓ Deciduous material: no leaves, no winter burn

Winter Burn: Prevention

- Select cold hardy plants!
- Plant in mid to late spring, but fall is good time to plant for some species, especially deciduous
- Do not plant evergreen species after Sept., lack of root growth before ground freezes
- Plant sensitive plants on north, N.E. or eastern side of building), out of winter sun and wind
- Some evergreens best planted in partial shade

Winter Burn: Prevention

- Use windbreaks to reduce winter burn
- Reduce N fertilization in summer, hardens off
- Water evergreens through fall so well hydrated
- Keep plants healthy, free of insects and diseases
- Mulch base of plants, but away from trunks/crown

Winter Burn: Prevention

- Anti-transpirants?
  - Must reapply often, washes off
  - Limited to no effect in preventing winter burn
  - Clogs stomates, prevents evapotranspiration
  - Water uptake from roots reduced
  - Reduces photosynthesis
- Use of burlap, snow fencing, canvas, etc. placed on south, S.W. and windward sides of evergreens; double burlap layers in late Nov.
- Add stakes first to hold up burlap
- Leave top open for air and light penetration

Winter Burn: Treatment

- Wait until mid spring to prune out dead material
- Prune back to live, green tissue
- Dead leaves will not green up
- Lateral buds more cold hardy, eventually fill in dead areas
- Many shrubs recovered, no damage evident by early to mid summer
- Some plants too far gone: removal

Soil (Frost) Heaving

- Surface soil with little mulch or snow
- Problem beginning and end of winter
- Alternating freezing and thawing of soil
- Soil heaves plant crown up and down
- Roots and plant crown become exposed
- Susceptible to desiccation and cold injury

Soil (Frost) Heaving

- Roots killed at soil temps. < 15-20ºF
- Soil temps. > air temps.
- Moist soil holds more heat than dry
- Frost penetration deeper and colder for dry, sandy soil
- Fall planted, newly planted, shallow-rooted groundcovers, strawberries and herbaceous perennials susceptible

Soil (Frost) Heaving

- Water thoroughly until ground freezes
- Use 3-4" wood chip mulch, evergreen boughs, leaf compost, hay, loose material over newly planted material
- Moderates soil temps., prevents rapid fluctuations
- Snow cover helps insulate

Snow and Ice Damage

- Limbs may bend or break, deforming trees, ruining form
- Internal cracks, bark tearing
- Wet snow, freezing rain, and ice build up on branches causing excessive loading
  - ✓ Ice-covered twigs can weigh 12-40 times as much than twigs without ice (Pirone, 1978, Semonin, 1978)
  - ✓ 50 tons of ice formed on 50' evergreen tree (Semonin, 1978)
- If high winds follow icing events
  - ✓ Branches higher up in trees can break

Snow and Ice Damage

- Trees more susceptible to snow/ice damage:
  - ✓ Younger trees bend and recover more than older trees
  - ✓ Multiple leaders: maple, elm, honeylocust
  - ✓ Weak-wooded, fast growing trees: poplars, elms, willows, black locust, Freeman and silver maples, catalpa, birches, black and choke cherries, Japanese pagodatree
  - ✓ Faster growing evergreen trees: white and Scots pines

Snow and Ice Damage

- Trees more susceptible to snow/ice damage:
  - ✓ Clump form, multiple trunks: birches, smaller maples, Amur chokecherry, magnolias
  - ✓ Poor form, narrow branch crotches, included bark
  - ✓ Trees with internal decay, cavities, severe cracks
  - ✓ Upright evergreens: arborvitae, juniper, yews
  - ✓ Unpruned/untrained trees more injury susceptible
  - ✓ Watersprouts in crown after damage, weak wooded, no branch collar, leads to further failure

Snow and Ice Damage

- Snow plow injury evident after snow melt
- Trunks can be seriously injured
- Shrubs damaged from being driven over
- Shrubs with broken branches from too much snow plowed over it

Snow Damage Prevention

- Gently brush off snow but avoid breaking branches
- May have to loosely tie up branches with old nylons 2/3 of the way up trunk to stay upright
- Tie evergreens with multiple leaders in late fall
- Remove in spring

Ice Damage

- Leave plants alone; some will recover
- Let ice melt naturally, very brittle
- Removing ice can cause more damage
- Damage worse in high winds

Snow and Ice Damage Prevention

- Prune when young to avoid double leaders
- Remove branches with narrow crotch angles to trunk
- Large competing limbs may need cabling

Ice Damage

- Limbs touching powerlines: call utility company only
- Call an ISA Certified Arborist (with liability insurance), especially if broken limbs still attached to tree: https://www.waa-isa.org/find-certified-arborist/
- If cannot reach with pole pruners, hirer an arborist
- More homeowners killed by falling limbs: ladders
- Wait till ice melts
- Remove fallen, broken limbs if blocking roads or sidewalks
- If severe damage, may need to remove tree

What will this year look like?

- Start of winter season in October
  - ✓ Record snow and cold on Halloween
- Only in first stage of acclimation, not fully hardy
- Deciduous trees still had leaves, no fall color, leaves remained on plant
- Marginally hardy plants may have damage
- See damage in late April-May?

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