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Abiotic Plant Disorders
Symptoms, Signs and Solutions
A Diagnostic Guide to Problem Solving

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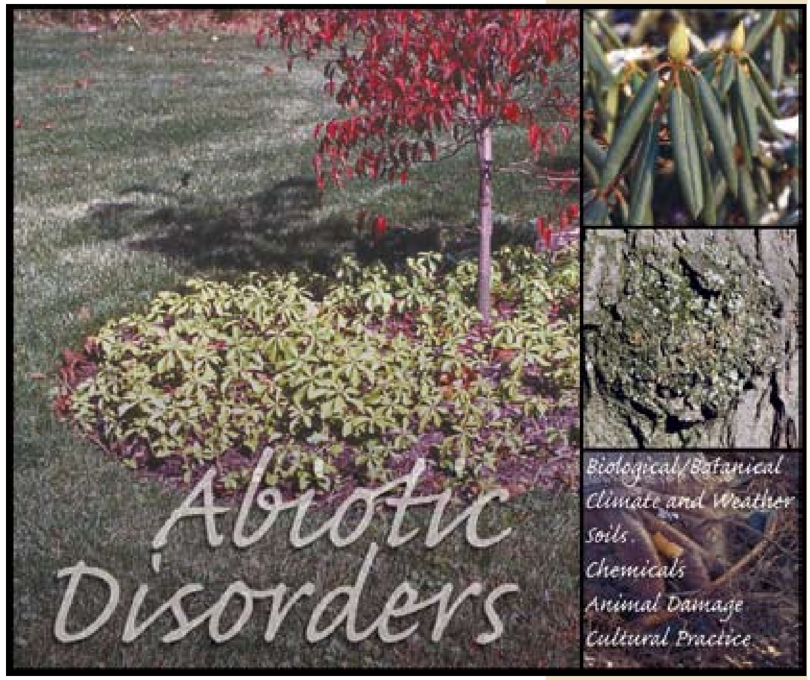
The term "abiotic disorders" refers to a wide array of plant problems. We use the word "abiotic" to indicate that the symptom is not caused by a biological agent such as an insect, mite or pathogen. Abiotic disorders are associated with non-living causal factors such as weather, soils, chemicals, mechanical injuries, cultural practices and, in some cases, a genetic predisposition within the plant itself. Abiotic disorders may be caused by a single extreme environmental event such as one night of severe cold following a warm spell or by a complex of interrelated factors or events. They can also be caused by chronic conditions such as a prolonged drought or plant selection inappropriate for the existing site conditions (e.g., planting an acid-loving species in an alkaline soil).



Abiotic plant problems are sometimes termed "physiological disorders". This reflects the fact that the injury or symptom we see, such as reduced growth or crown dieback, is ultimately due to the cumulative effects of the causal factors on the physiological processes needed for plant growth and development. When a tree is affected by severe drought, for example, water stress will result in closure of the pores, or stomata, on the leaf. This conserves water in the leaf but also reduces the rate of photosynthesis and the ability of the plant to produce sugars for growth. If the drought stress occurs during hot weather, stomatal closure also limits the cooling effect of transpiration, and leaf scorch may occur. Nutritional imbalances also limit growth by reducing photosynthetic rate and other physiological and metabolic processes. Some plants, such as pin oak, have a limited ability to take up iron under alkaline soil conditions. Iron is essential for synthesis of chlorophyll, so pin oaks on alkaline soils frequently develop severe leaf yellowing or chlorosis and have reduced rates of photosynthesis.

The cumulative and subtle nature of many physiological disorders can often make them difficult to diagnose. An extreme event such as a severe late freeze or a misapplied herbicide is an obvious "smoking gun" to indicate the underlying cause of injury. More often, however, diagnosing abiotic problems requires careful consideration of plant and site factors through a process of elimination to determine the source and potential remedy for the problem.

Abiotic disorders are usually classified by causal factor or symptom. In this bulletin, we will present abiotic disorders whose origins are due to biological/botanical factors, environmental (climate and weather) conditions, soil conditions, chemical applications, animal damage and cultural practice. We will also provide a framework for diagnosing problems and suggest steps to mitigate abiotic injuries before or after they occur.

ABIOTIC plant disorders are associated with non-living causal factors.

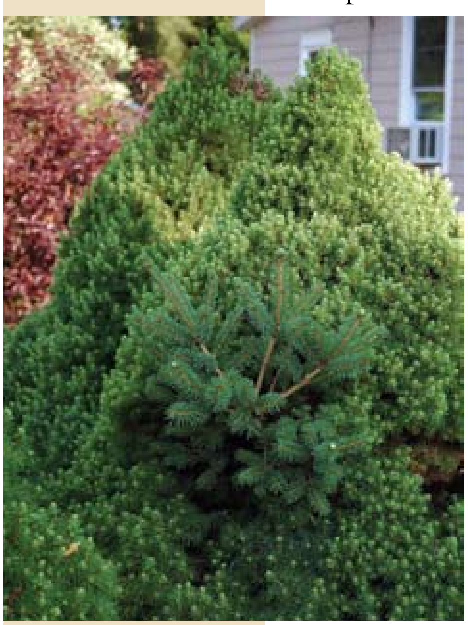
Biological/Botanical

Genetic reversion on Harlequin maple.

The genetic makeup of a species is expressed through its physiological and morphological characteristics. Whether these characteristics are perceived as normal or abnormal depends on the individual circumstances and location where they are found. Understanding the basis for these characteristics can be useful in determining whether they need to be addressed and can aid in outlining a course of action. In many cases, these characteristics are a fact of nature and simply need to be appreciated for what they are; in other cases, they can be altered or corrected by simple measures. Here are some common abiotic abnormalities that are biological/botanical in origin.

Genetic mutations and reversions

Genetic anomalies are prevalent in the plant world and often garner much attention. For example, seedling growers often find mutants in their nursery beds. Albino seedlings are common seedling mutants. Because they lack chlorophyll, these seedlings quickly die off once they exhaust energy reserves from the seed. However, many mutants are stable and sustain growth. These stable mutants can exhibit unique form, foliage, flower, stem and other characteristics that warrant their development and introduction into the trade.



Genetic reversion on dwarf Alberta spruce.

For unknown reasons, some of these mutant cultivars exhibit a tendency to produce shoots that revert to their species type. Genetic reversions are fairly common on dwarf Alberta spruce and Harlequin Norway maple. To maintain the cultivar characteristics, genetic reversions need to be pruned out quickly and completely when they are observed.

Chimeras

Chimeras are botanical abnormalities that are often confused with nutritional or chemical disorders. "Chimera" is a term used to describe a single plant with two genetically different tissue types. Leaf variegation is the most common example of chimeras in plant species. The difference in foliage color and the banding of those colors are due to cell mutations in the meristematic tissue layers. Chimeras can be stable, in that the genetic differences are consistent and reproducible. These chimeras have spawned numerous of our variegated plant cultivars. Chimeras can also be unstable and unpredictable, surfacing sporadically on either shoots or individual leaves. The Bumald spireas are known for the sporadic appearance of unstable leaf chimeras. The stability of the chimera depends on the tissue layer where the mutation occurs. If you discover variegation on an individual stem and not over the entire plant, it is possible that it is a chimera and not an abiotic disorder related to plant nutrition or chemical injury.

Chimera on Anthony Waterer spirea.

Leaf abscission and retention

Leaves emerge in the spring, function during the growing season, turn colors and drop in the fall. Leaf drop occurs whether the plant is deciduous or evergreen; it just happens with different aged leaves. There are times when leaf drop or retention is normal and times when it may be related to a plant problem.

Leaf abscission or drop is triggered in the fall by seasonal changes in daylength. Chlorophyll degrades, and the plant hormones abscisic acid and ethylene cause an abscission layer to be formed at the base of the petiole. In evergreen species, needles usually function for 2 to 3 years, depending on the species. Normal leaf yellowing and abscission occur on the insides of the stem on 2- or 3-year-old wood. Yellowing or browning of needles on the shoot tips is a sign of problems. If a stem or leaf is injured or dies before seasonal changes occur, abscission layers will not form and leaves will remain on the stem. Leaves remaining on isolated stems in the fall or winter are signs of stem or leaf problems. Stems may be girdled by an insect borer or mechanical injury, causing a break in vascular connections resulting in stem death and leaf retention. An early killing frost prior to the formation of the abscission layer may cause dead leaves to be retained throughout the winter.

In some deciduous plant species, leaf retention is a normal characteristic. Marcescent leaves are the dead leaves retained by some plant species. Typical examples of genera exhibiting marcescent leaves are oaks and beeches. Species within these genera do not complete the formation of the abscission layer until the following spring. Leaves will fall when bud break occurs and stems resume growth. If leaf retention is a concern, identify the plant species, check for evidence of stem injury, and review recent weather conditions.

Graft incompatibility

Graft incompatibility is due to the failure of the bud or graft union between a scion and an understock. For unknown reasons, the tissues of the two plant parts do not form a stable union. Failure of the union disrupts translocation in both the xylem and phloem and influences plant performance with age. In production systems, signs of graft incompatibility may be visible as an uncharacteristic intensity of the fall color. Disruption of translocation leads to a buildup of sugars during leaf senescence that intensifies fall foliage color. This is especially the case on *Acer rubrum* cultivars with known incompatibility problems. Graft incompatibility issues on these *Acer rubrum* cultivars led to production on their own roots. Graft incompatibility remains a concern in fruit tree production. Incompatibility is not easily detected and can surface at various times in a plant's life. Unfortunately, for many it surfaces when the trees are mature and affected by wind or some other environmental condition. Graft incompatibility can result in semimature trees snapping off at the base in wind storms. Failure of the tissue union is visible at the trunk/root collar. On plant species with known problems, check on the budding or grafting practices during production. Another form of incompatibility occurs when there are differences in growth rates between the scion and the understock. These differences can lead to disproportional growth at the junction of the two tissues.

Leaf retention on oak.

Galls and burls

Galls and burls are abnormal growths on woody plants. They can occur on branches, trunks and, in some cases, on roots of woody plants. Galls may be caused by an insect or disease; however, the origin or causal factors for burls and other callus outgrowths are unknown. Abnormal growths form through a proliferation of cells. These cells continue to develop and do not differentiate into normal tissue types. In some cases, the outgrowth results from a cluster of shoots. Each year, new shoots are initiated and increase the layers of the mass.

Proliferation of trunk sprouts leads to callus buildup.

Callus knob formed from reoccurring trunk sprouts.

Branch architecture

Genetic makeup contributes to branch architecture and the angle of attachment in plant species. Branch angle is a predictor of wood strength and a plant's ability to withstand compromising environmental conditions. Even though the loss of branches may be due to wind or ice load, the genetic predisposition for weak branch or wood strength is the inherent basis for the problem. Common knowledge tells us that vigorous upright branches with narrow attachment angles are prone to storm damage. Horizontal branch angles offer potentially greater wood strength. To ensure the stability and longevity of species with narrow branch angles or multistemmed upright crowns, corrective pruning should be performed on a semiregular schedule. Consider cabling or bracing on plants too old for corrective pruning.

Weak branch angle.

Environmental (Climate and Weather)

Climate and weather are certainly unpredictable, as are their impacts on plants. Climate and weather present a complex of environmental conditions and encompass a range of potential injuries. Fortunately, experience and our ability to learn from the past aid our preparation. Understanding climate and weather's impacts on plants involves plant science, a little meteorology, a dash of physics and maybe some chemistry. These disciplines set the foundation for our dealing with the interrelated environmental factors of temperature, light, precipitation and air flow, and their potential direct and indirect effects.

Low-temperature injury

Low-temperature impacts on plants can be classified as chilling or freezing. Chilling injury or chilling stress, as it is often termed, is associated with temperatures above freezing but low enough to cause injury. Chilling injury is due to a sudden drop in temperature during an

Leaf curl on broad-leaved evergreen due to low-temperature injury.

Low-temperature injury on ground cover.

Low-temperature injury on boxwood.

Low-temperature injury on deciduous shrub.

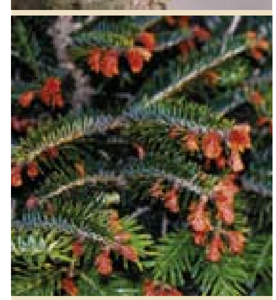
active period of plant growth or development. The greater the drop in temperature from normal, the more likely injury will occur. The extent of the injury may cause a reduction in photosynthesis or other metabolic processes, an alteration in growth or death of the exposed plant tissue. For example, a substantial drop in temperature during new shoot growth and leaf expansion may result in damage to the terminal meristem and a loss in shoot growth. Other signs of chilling injury may include wilting, desiccation and/or a physical distortion of plant parts. Chilling injury is less serious than freezing injury on most of our herbaceous and woody plants. Plants can usually grow out of the damage inflicted by chilling injury.

Freezing injury is easier to identify and a lot more damaging. It is caused by subfreezing temperatures. The impact of subfreezing temperatures may be felt from as little as one overnight episode or from a more sustained exposure episode. Plants subjected to subfreezing temperatures may exhibit ice formation in the vascular vessels, in the spaces between the cells and/or within the cells. The extent and pattern of ice formation vary with the plant tissue and its condition. Ice formation in the spaces between cells is usually not fatal, but it causes water to leave the cells, causing dehydration. If the freezing episode is cold and long enough, it can result in freezing within the cells. Internal or intracellular freezing ruptures membranes and leads to cell death. Freezing damage begins with dehydration and ultimately ends in plant tissue death. Typical signs of freezing injury are a blackened/brownish discoloration or bleaching of plant tissue. The severity of the freezing damage depends on the type of frost injury and the plant parts affected. If the freezing injury kills a significant number of buds or cambial tissue, the plant may die outright or suffer so much crown die-back that it becomes unusable or unacceptable in the landscape. More commonly, however, freezing injury may be limited to flower buds and minor shoot dieback. This damage may require corrective pruning and time to allow the plant to grow out of the damage.

Understanding low-temperature injury begins with an examination of cold hardiness. Cold hardiness refers to a plant's ability to withstand cold temperatures without sustaining injury. The level of hardiness that a plant can attain is based on genetics, preseason conditioning and its current condition. The genetic origin of a plant contributes to its ability to "harden". Plants of a given species originating from warmer climates may not be as cold hardy when moved into northern regions as the same species from northern regions. The same is true for heat tolerance when northern plants are moved to the South. Origin, not production location, is the governing factor in determining hardiness capability.

Preseason conditioning refers to the physiologic and metabolic changes that occur within a plant as it begins hardening. The process leading to cold hardening is generally considered a three-stage process. The first stage occurs at the end of the growing season. Growth has ceased, plants have formed terminal buds, and carbohydrates are accumulating in stem and root tissues. Short days and cool night temperatures of early autumn begin the acclimation. During acclimation, metabolic changes occur within the plant that allow it to withstand lower temperatures. During the initial stages of acclimation, however, hardiness levels may be lost as easily as they were obtained if temperatures rise or other environmental factors promote the resumption of growth. Acclimation continues and hardiness tolerance increases with consistent exposure to temperatures at or slightly below freezing. The final stage, the deepest level of cold hardiness, is achieved after prolonged exposure to subfreezing temperatures. Plants are said to be at midwinter levels when they reach their maximum cold tolerance for a given season. In the Midwest, maximum levels of hardiness are usually achieved by early January. As spring approaches, plants begin to deharden or lose cold tolerance with increasing temperatures. Late frosts can cause injury during this dehardening phase when plants begin to break bud and initiate shoot growth. Remember that plant parts differ in their cold tolerance.

Chilling injury on newly emerged leaves of ginkgo.



Late frost injury.


Frost crack.


Sunscald and frost crack.

Flower buds usually do not achieve the hardiness levels that vegetative buds and stem tissue do.

The last factor contributing to a plant's ability to achieve maximum cold hardiness is plant health. Healthy plants achieve their cold hardiness potential; stressed plants may not. It is important to note that plants stressed by drought, flooding, nutrient deficiencies, transplant shock or pest problems may not become fully hardy.

Any situation that reduces a plant's ability to produce or store carbohydrates may influence its ability to attain levels necessary to avoid low-temperature injury. The best insurance for hardiness is plant health. In summary, genetics set the foundation levels for low-temperature tolerance of a plant. Preseason conditioning and plant health determine whether a plant can approach these levels.

Sunscald and frost cracking

Sunscald and frost cracking are the result of the interaction of light and temperature.

They are caused by thawing and freezing due to a rapid fluctuation in stem temperatures. Exposure to afternoon sun causes an increase in stem temperature and the subsequent thawing of stem/trunk moisture. As the sun sets, temperatures drop rapidly. If the temperature drops below freezing, ice crystals rupture internal tissue. Sunscald and frost cracking occur from the same causal conditions. In sunscald, the cambium, phloem and xylem are damaged, a sunken area appears on the trunk, but the bark is not split. Frost cracking exhibits the same internal damage with vertical splits in the bark. The splits can reopen and close with changes in air temperature. As temperatures increase in spring, the bark tissue dries and the cracks remain open. Thin-barked plants are prone to sunscald and frost cracking, especially when subjected to southwest exposures. Tree wraps can minimize sunscald and frost cracking, but thin-barked plants may always be susceptible to this problem if environmental conditions favor temperature fluctuations.


Frost cracking.

Winter desiccation

Winter desiccation is not considered a direct result of low temperature but originates from the interaction of temperature and wind. As the name implies, winter desiccation is actually a form of drought stress. Desiccation occurs when water absorption by the roots can not replace water loss through the foliage, buds or stems. Transpiration and evaporation from plant parts increase when temperatures rise above freezing. This is especially true on bright, sunny, windy days. If soils are frozen, water absorption can not replenish plant tissue moisture, and dehydration and eventual desiccation injury occur. Signs of desiccation begin with leaf curl or wilting, and progress to a browning of leaf margins and/or bud scales. If conditions are severe or persistent, browning will consume the entire plant part. If snow cover is present, a tell-tale snowline above which damage occurred can be observed on the plants. Desiccation usually affects the foliage of broad- and narrow-leaved evergreens; buds and stems for the most part are not affected unless adverse conditions are prolonged or compounded by freezing injury.

Desiccation injury varies with plant species, plant part, soil moisture content,

Winter desiccation on broad-leaved evergreens.

depth of frozen soil, snow cover and wind velocity. Desiccation is common on narrow- and broad-leaved evergreens. In the Midwest, it occurs for the most part when the depth of frozen soil increases in mid- to late winter. Desiccation injury can be minimized or prevented by protecting plants with screening or applying an anti-transpirant. Wrapping or screening not only protects from wind but helps minimize the degree of temperature fluctuations on the plant parts. Wrapping protects the entire plant; screening is usually positioned to intercept prevailing winds. Wrapping may be the smart horticultural alternative on prized ornamentals or in high-profile landscapes. Anti-transpirants are another viable means of protection, but keep in mind that they must be applied and allowed to dry at temperatures above freezing. Application should be made before we anticipate injury, which in the Midwest is early to mid-January. A good time to consider applying anti-transpirants is during our typical January thaw. Degradation of the anti-transpirant due to weather may require reapplication to extend the protection through the critical period.

Frost heaving

Frost heaving results from the alternate freezing and thawing of soils. Heaving exposes the roots to cold and desiccation and is especially a problem on newly planted or shallow-rooted plants. Fall-planted ground covers, perennials and small container shrubs are highly vulnerable. Ground cover plugs and small container plants should be fully planted in soil. This may sound obvious, but with a tendency to plant high, these plants are often found planted in the mulch rather than completely surrounded by soil. In addition, a uniform mulch layer aids in preventing rapid soil temperature fluctuations. In larger container plants, planting high in the mulch layer may expose the upper level of the root system enough to influence plant quality the following spring. Proper planting technique is the best defense against frost heaving.

Snow and ice

Ice and snow accumulation on branches can cause internal splits or cracks, bark tearing and/or breakage. Plant architecture, branching structure and wood strength can be predictors of damage from excessive snow or ice load. Unfortunately, hidden cavities in the wood or flaws in branch attachment can increase the damage potential. Plants with multiple stems can be tied to provide support. This may be especially helpful on upright narrow-leaved evergreens. Excessive amounts of snow can be carefully removed to alleviate the stress on lateral branches. Ice should be allowed to melt naturally. Branches

Winter desiccation on fir.

Upright branches of arborvitae are tied to prevent snow and ice injury during winter.

Birch is often temporarily bent by snow and ice loads on branches.

Ice load on pine.

Photo: Erich G. Vallery, USDA Forest Service, www.forestryimages.org become extremely brittle when laden with ice. Mechanically removing the ice may increase the amount of injury. Once the ice has melted, the branches will usually return to their normal positions.

Drought and heat

Moisture stress and extreme heat can greatly reduce plant growth, especially caliper growth. Heat can directly injure plants in extreme conditions, but the principal effect of heat is increased water loss and plant moisture stress. Moisture stress can cause significant mortality, particularly soon after transplanting. Wilting is the most common initial symptom of drought stress. Hardwood leaves and conifer leaders will curl or droop. As drought progresses, hardwood trees may begin to shed leaves, and conifers may begin to drop interior needles. Drought stress, however, reduces growth before visible symptoms such as wilting or leaf shedding become apparent. Even moderate stress can cause the stomata on the leaves to begin to close, reducing photosynthetic production. Caliper growth is highly sensitive to water stress because cell turgor is required for radial expansion of new wood cells formed by the cambium. In fact, the high sensitivity of radial growth to moisture forms the basis of dendrochronology, the science of using tree rings to reconstruct past climates. Drought and heat stress can also cause some plant species to enter into an imposed dormancy. This mild state of dormancy can satisfy the chilling requirements of some species, causing isolated out-of-season flowering when the stress is relieved.

Wilting of conifer leaders.

Sunburn on summer foliage.

Leaf scorch on oak.

Plants can also be subjected to sunburn when shaded foliage is exposed to sunlight during hot, dry periods. Leaves emerge and fully expand in the canopy of plants over the course of spring and early summer. Leaves develop and acclimate to light levels. Exposing shaded leaves to full sun during periods of high light and moisture stress can produce a sunburned appearance on the foliage. To avoid summer sunburn on foliage, do not prune during hot, dry periods unless soil moisture levels are adequately maintained.

To understand plant water relations, it is important to remember that water forms a continuous path from the soil through the plant and into the atmosphere. This is often referred to as the soil-plant-atmosphere continuum. Any factor that reduces water uptake from the soil – such as low soil moisture, loss of roots during transplanting or frozen soil – or increases evaporative demand and transpiration to the atmosphere – such as high temperature or low humidity – can increase plant moisture stress.

Flooding

Though we usually think of drought as a limiting factor for plants, excess water can also be a problem. Plants vary widely in their tolerance of flooding. Many bottomland species can survive for months with their roots under water; other species may be killed by only a few days of inundation. Flooding causes several problems for plants that are not flood-tolerant. Without oxygen, roots begin to undergo anaerobic respiration, which results in the production of toxic compounds in the plant. Plants undergoing water stress may exhibit symptoms such as wilting that are similar to symptoms of drought stress. Premature fall color is typically a sign of moisture stress, either too much or not enough. Excessive rain, standing water and poor drainage in late summer can initiate premature fall color on the affected plants. The same symptom exists for plants in severe drought stress.

One of the prime indicator species for these types of summer moisture stress is *Euonymus alatus* 'Compactus', burning bush.

Lightning and hail

Summer storms are a normal occurrence in the Midwest, and with them come lightning and, in some cases, hail. Trees in particular can be killed outright or severely damaged by lightning strikes. When lightning strikes a tree, it can fracture and splinter the wood or travel down from the entry point to the ground, carving a groove in the conductive tissue and bark. The extent of the injury depends on the intensity of the lightning, where it enters, the moisture level in the tissue and the wood characteristics. Recommendations for treating lightning strikes are relatively simple: clean the damaged areas, removing splintered wood and tracing loose bark back to firmly seated bark, and provide cultural practices that invigorate and promote plant growth, such as irrigation and fertilization.

Lightning strikes can result in extensive damage to bark and underlying cambium.
Photo: Robert L. Anderson, USDA Forest Service, www.forestryimages.org

Hail shreds and tears susceptible plant parts. It affects leaves, young stems and branches, and in severe storms with large hail, it can damage or bruise bark. Damage from hail is usually immediate and short-term. No treatment is necessary unless light pruning is needed to remove broken stems and branches.

Soils

An understanding of plant/soil relationships is key not only to solving problems but to avoiding them in the first place.

Soil type

"Soil texture" refers to the mixture of sand, silt and clay particles in the soil. It influences aeration, water retention, drainage and nutrient-holding capacity. Soil texture and its relationship to water movement through soils is one of the most important factors leading to abiotic plant problems. We often hear the phrase "moist, well-drained soils" when referring to plant preferences. Unfortunately, this condition is not the rule in most planting situations. Sandy soils need amendments to increase water- and nutrient-holding capacity. Clay soils need alterations to facilitate drainage. A thorough examination of soil physical and chemical properties can aid in avoiding common problems associated with water deficits, flooding and nutrient disorders.

Death due to poor soil drainage.

Chlorosis on pachysandra due to excessive moisture stress.

Shallow root development on compacted soils.

Top: Chlorosis due to nutrient deficiency.
Middle: Manganese deficiency.
Bottom: Normal red maple leaves.

Nutrient problems

Nutrient problems rarely kill plants outright, but proper nutrient management is essential to optimizing growth and maintaining high quality plants. Most nutrient problems are related to nutrient deficiencies, although nutrient toxicities may occur.

The extent and nature of nutrient deficiencies can depend on several factors, including soil type or media in production systems, site conditions in the landscape and the plant. Seventeen elements have been identified as essential for plant growth. Plants obtain carbon, hydrogen and oxygen from air and water. The remaining elements are derived from the soil or from a fertilization program. All of these are involved in one way or another with key physiological functions in the plant. For example, nitrogen and sulfur are components of essential amino acids needed to build proteins. Magnesium is a key element in chlorophyll molecules, and iron is involved in chlorophyll synthesis. In theory, any essential element may be limiting for growth. As a practical matter, only a handful of elements are commonly limiting in field nursery production and landscape systems. In the upper Midwest, the most common elemental deficiencies we observe are nitrogen, phosphorus, potassium, iron, magnesium and manganese. Iron and manganese deficiencies are often linked to specific plants and to alkaline soil. Nutrient deficiency symptoms include overall loss of vigor, reduced shoot growth, general yellowing or chlorosis of the leaves, interveinal chlorosis, marginal necrosis and, in severe cases, total leaf necrosis.

Nutrient deficiency on white pine.

Nutrient toxicities are less common in plants than nutrient deficiencies, but they can occur, particularly with some micronutrients. With elements such as boron or copper, the difference between sufficiency and toxicity is relatively small. Caution should be taken when using micronutrients in fertilization programs. If a soil test or foliar analysis indicates these elements are needed, one strategy is to apply them as split applications to reduce the possibility of toxicity. Nutrient deficiencies and toxicities need to be confirmed by a soil and leaf tissue analysis.

Salinity is the concentration of water-soluble salts in the soil or production media. These salts are necessary for plant growth and development, but soluble salt levels in high concentrations can cause toxicity problems. Typical salts causing problems on plants are chlorides, sulfates and ammonium. Soil or media salinity is determined through electrical conductivity measurements. The most effective way to alleviate the negative impact of high soluble salts is through leaching. Leaching is effective in container production systems, but on field soils and in the landscape, the effectiveness of leaching depends on soil drainage.

Soil pH refers to the acidity or alkalinity of the soil. Soil pH influences the availability of nutrients in the soil, the solubility of some nutrient elements and the activity of soil microorganisms. It is generally accepted that the optimal pH for plant growth and the availability of a broad spectrum of nutrients is between 5.5 and 6.5 (slightly acid). As pH drops below or rises above this range, the solubility/availability of some nutrient elements may become limiting or toxic. Iron and manganese are known to be limiting at soil pH levels above 7 (levels above 7 are alkaline). Aluminum, manganese and copper can be toxic at soil pH levels below 5.5 (strongly acid). Knowing the pH of soils and container media is essential for maintaining adequate growth and development as well as for diagnosing abiotic disorders.

Chemicals

Exposure to various chemicals can cause either chronic or acute plant injury, depending on the type and duration of the exposure.

Salt injury

Winter brings snow and ice and with them the need for deicing materials. Salt used for deicing affects plants in the landscape when it accumulates on stem tissue by airborne sprays and/or in soils because of runoff from treated areas. Soil buildup is especially a problem in landscape beds adjacent to sidewalks or curbs where snow accumulates through plowing and shoveling. Deicing salts damage plants through direct sodium chloride toxicity, dehydration due to osmotic stress, reduced cold hardiness due to salt buildup on buds and stems, and/or its influence on soil nutrients. Salt injury usually expresses itself as terminal shoot dieback, bronze foliage on evergreens, bleaching of ground covers and turf, or total plant death in the case of ground covers and perennials. Successive years of dieback on woody trees and shrubs could result in a "witches' broom" appearance on the outer branches. Given winter conditions, it is essential to deal with deicing in the landscape design phase. Deicing practices must be considered in plant selection and landscape bed design in close proximity to paved surfaces. If we are not fortunate to have an input on design and selection, we must intercept airborne salt through screening or apply more plant-friendly deicing materials such as calcium magnesium acetate.

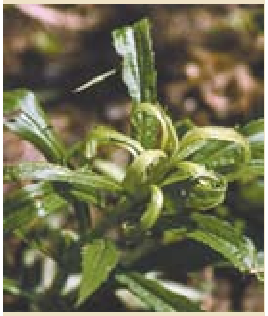
Salt injury on taxus.

Herbicides

Herbicide injury symptoms vary with the plant and the herbicide applied. Understanding the mode of action of herbicides and their effects on non-target plants will aid in recognizing injury symptoms and distinguishing herbicide injury from other abiotic and biotic problems. Three widely used types of herbicides are growth regulators, photosynthetic inhibitors and plant enzyme inhibitors. Growth regulatory herbicides such as 2,4-D are plant hormones that act by causing irregular growth. Essentially, weeds grow themselves to death. Symptoms of plant growth regulator herbicides' action on weeds include leaf cupping and twisted, distorted growth. These same symptoms are found on non-target plants. Photosynthetic inhibitors such as atrazine and simazine act by interrupting normal photosynthesis. These compounds block the mechanism that transforms sunlight into energy. Photosynthesis inhibitors require sunlight to work. Injury symptoms, which

Two examples of improper use of non-selective herbicide.

Salt injury on turf.



Leaf cupping/ curling due to a growth regulator herbicide.

Marginal chlorosis from herbicide injury.

appear on older leaves first, include leaf yellowing and interveinal chlorosis. Plant enzyme inhibitors such as glyphosate are translocated in the plant and act on the enzymes that synthesize amino acids, protein and other plant compounds. Injury symptoms, including a yellowing and browning of leaves, do not appear immediately. Some herbicides will cause root swelling and stunted shoot growth.

If herbicide injury is suspected as a causal factor, identify the compound applied, review its mode of action and determine its persistence in the soil. This information will be useful in identifying proper treatment. Herbicide injury produces many of the same symptoms as nutrient deficiencies or toxicities. Nutrient deficiencies and toxicities can be eliminated as causes by leaf tissue and soil analysis.

Pesticides

Insecticides, fungicides and other chemicals used in the control of plant pests can cause problems on both targeted and non-targeted plants. Several factors can influence whether the pesticide application is the solution or becomes part of the problem.

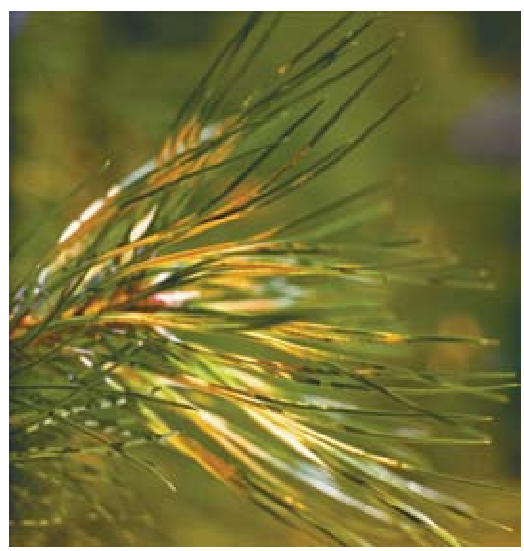
As with any chemical application, injury will depend on the type, concentration and application rate of the compound; the plant species, its stage of growth and physiological condition; and atmospheric conditions – light, temperature, humidity and wind. Finding the perfect time to apply pesticides is always a challenge. Proper handling of the pesticides and close monitoring of weather conditions can avoid application-related injuries. Application injuries exhibit the same symptoms as nutrient disorders and other chemical applications. In most instances, leaf chlorosis, marginal and/or spotted necrosis, and total leaf necrosis are the visible symptoms.

Air pollution

In some parts of the country, air pollutants can cause acute or chronic injury to plants. Air pollution impacts on plants are most commonly found on the foliage. Injury symptoms include interveinal necrosis, marginal or tip necrosis, white or brown flecking or stippling on the leaf surface, and various degrees of chlorosis. The extent of the injury is very much dependent on other environmental and atmospheric conditions. Factors include the type, concentration and the length of exposure to the pollutant; the plant species, its stage of growth and physiological condition; and atmospheric conditions – light, temperature, humidity and wind.

Ozone is one of the more common pollutants that can damage plants. Ozone is produced in the atmosphere through a photochemical reaction between volatile hydrocarbons and nitrogen oxides in the presence of light. Ozone injury, if it is an issue, will generally occur in the summer, when temperatures support reaction rates.

Sulfur dioxide is another pollutant that can injure plants. Sulfur dioxide emissions result from the burning of coal and other petroleum products. Improved filtration technology and emission controls have substantially reduced sulfur dioxide injury. Isolated cases of volatile chemical spills or emissions may subject plants to injury. Such cases are usually easily diagnosed because of the close proximity of the plants to the isolated event.



Ozone damage is sometimes evident as stippling or bleaching of needes in conifers.
Photo: Peter Kapitola, State Phytosanitary Administration, www.forestryimages.org

Animal Damage

The issue of food supply and demand is a concern when we are investigating animal damage. When forage becomes limited, many of our ornamentals become prime targets for deer, rabbits, squirrels, mice and other rodents. Some ornamental species such as tulips, hostas and taxus are preferred over natural forage. Deer browse is obvious on taxus, arbovitae and other evergreens. Squirrels may feed on the petioles of newly expanded leaves or gnaw on the upper sides of branches within tree canopies. Rabbits, mice and other rodents focus on the ground-level portions of deciduous trees and shrubs. Habitat reduction is the first line of defense against small rodents. Unfortunately, many of our prized plant compositions also make for ideal cover. Minimizing cover may deter feeding but does not eliminate it. Caging plant crowns, wrapping wire mesh around the bases of the plants, applying feeding repellents and using poison baits work reasonably well. Quite often our best bet is to apply multiple methods in various combinations. When repellents are used, keep in mind that they degrade in winter weather and need to be reapplied throughout the season. Poison baits are often used for mice and should be positioned to avoid feeding by other animals.

Squirrels foraging on the petioles of newly expanding leaves cause leaf drop in late spring/early summer.

Squirrel gnawing leads to extensive stem decay.

Bark stripped by porcupines.

Cultural Practices

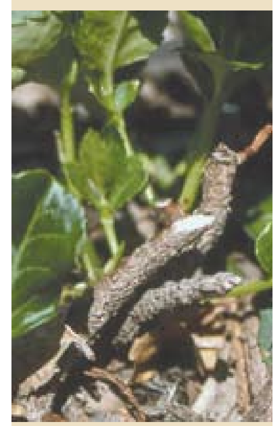
Cultural practices are designed to promote and maintain plant growth and development. The same practices designed to promote plant health can at times be the cause of abiotic problems.

Planting process

The planting process involves the pre-planting examination and evaluation of the plant stock type (bare-root, container, balled and burlapped [B&B], mechanical tree spade), the actual physical process of planting and the follow-up maintenance. Problems related to the planting process can originate within each of these. Consider the idiosyncrasies with each of the previously mentioned stock types, for example, the depth of the trunk/root collar on B&B trees, encircling roots in container-grown plants, root desiccation on bare-root plants and glazing in mechanical tree spade plantings. Each one of these factors can contribute to the success or failure of the plants. Improper handling and planting procedure contribute significantly to abiotic consequences, especially when they're combined with soil or environmental limitations at the planting site. Symptoms related to poor planting procedures are similar to those of drought and flooding: shoot dieback, reduced leaf size, minimal shoot growth, root injury and poor root regeneration. If plant excavation is possible, examine the root system

Deer browse.
Minnesota Department of Natural Resources Archives, Minnesota Department of Natural Resources, www.forestryimages.org

Mice damage.
Robert L. Anderson, USDA Forest Service, www.forestryimages.org



Rabbit browse often looks like pruning cuts at the bases of shrubs.

Mechanical injury due to staking practice.

Crown dieback due to improper planting technique.

for white root tips and signs of root regeneration. Under drought or water deficits, white root tips will be absent, and existing roots will be dried and shriveled. Under excessive moisture and poor drainage, the root system will also lack white root tips and exhibit signs of anaerobic conditions. The blackened outer surface of the roots will slough off, exposing inner gray and water-soaked, stained tissue. In addition to the obvious plant symptoms, evidence of twine around the base of the trunk, scars from staking or other signs of mechanical injury may lead to conclusions on the causal factors and required treatment. Problems caused by poor planting procedures can be due to marginal plant stock quality; poor soil ball or container media moisture prior to planting or during establishment; improper planting depth, either too high or too low; compacted planting sites and poor drainage through the soil profile; improper irrigation scheduling following planting; and improper mulching practices.

Girdling roots

Girdling roots have long been recognized as an abiotic problem in both production and landscape systems. Encircling roots due to production methods, poor soil conditions, excessive mulch and narrow planting sites have contributed in one form or another to the problem. A distinction is sometimes made between two forms of girdling roots. "Girdling roots" refers to the condition that occurs when roots encircle upon themselves. Stem-girdling roots encircle the tree stem above the trunk/root collar. Both of these conditions affect the structural stability and anchoring of the plant and restrict the roots system's ability to adequately mine the soils. Stem-girdling roots compress the conductive tissue in the trunk, restricting translocation and eventually leading to trunk decay. Each situation causes a slow but progressive decline in plant performance. Treatment for girdling and stem-girdling roots consists of the selective removal of root sections. The extent of the removal varies with the condition and the length of time that the plant has been in place. Root removal may span several seasons to minimize stress to the plant. To eliminate or reduce the incidence of this problem, use proper planting procedure and long-term mulching practices. At planting, encircling roots should be cut or removed to ensure proper movement of new and existing roots into the surrounding soils. Excessive mulch layers around the bases of plants cause new roots to work their way upward to capitalize on optimal aeration, moisture and nutrient levels. Roots remain in the mulch layers and encircle as continued mulching maintains the preferred environment. Mulch layers should be removed periodically and problem roots cut and redirected.

Polytwine left on a B&B tree.

Plastic wrap and poly twine on a B&B shrub.

Girdling roots on red oak.

Mulch practice

The well-documented benefits of mulch support its widespread use. Mulch conserves soil moisture, reduces soil erosion, minimizes weed growth, moderates soil temperatures and contributes to soil fertility following decomposition. However, abiotic disorders can result from its improper or overuse. Excessive mulch and improper application lead to crown decay and plant decline. Problems associated with improper mulching include excessive moisture buildup on trunk collars and trunk decay, negative impacts on rooting depth, promotion of girdling roots, and nitrogen deficiencies in ground covers and annuals plantings.

Irrigation management

Proper installation and operation of irrigation systems is essential for effective and productive plant growth and development. Proper timing, frequency and rate of application not only ensure plant health and vigor but also provide for the efficient use of water resources. Supplemental irrigation is necessary during plant establishment. Demands for water during leaf emergence and expansion, shoot expansion and root initiation require water at fairly regular intervals. Once plants are established, however, irrigation can be adjusted accordingly. Abiotic problems related to irrigation operation can be due to moisture deficits resulting from improper scheduling and delivery or to flooding due to the failure of valves to shut off appropriately. Problems can be avoided by periodic checks to ensure that the system is operating correctly and delivery is appropriate for the plant, season and soil type.

Excessive wetness on trunk due to mulch buildup.

Maladjusted irrigation head.

Broken irrigation emitter on street tree.

Summary

One of the best strategies for dealing with abiotic disorders is to be proactive. Several routine planning and management practices can aid in either minimizing their occurrence and impact on plants or assisting in their timely diagnosis and treatment.

Plant selection

Select plants that are reliably hardy in your area. Remember that hardiness zones are based on long-term records of average low temperatures. Even species that are hardy for your zone may be damaged in an extremely cold winter or by fluctuations early or late in the winter. Match species to site environmental and soil conditions.

In addition, employ best management practices in producing, planting and managing the plants, whether they are in production or landscape systems.

Environmental conditions

Perform a thorough analysis of the site conditions. Site analysis includes identifying seasonal light and wind patterns, noting microclimatic variation on the site and recording site irregularities that could influence the way water moves on or off the site.

Document the characteristics of surrounding properties and identify potential influences from these areas. Have access to regional and local weather data.

Soil conditions

Know your soils and keep records of soil physical and chemical properties. Establish baseline data on soil nutrient and pH levels. In production systems, develop a routine schedule of soil testing.

Water quality

Water quality can dramatically affect nursery crops, especially in container production. Buy and learn how to use water quality monitoring equipment to check your pH and electrical conductivity. If you are using multiple water sources, be sure to have each source tested for alkalinity, calcium/magnesium ratio, soluble salts and sodium.

Irrigation management

Overirrigating wastes water and money and can cause as many plant problems as too little water. Consult with local Extension personnel and other experts in your area to develop a water management plan that supplies adequate water without overapplying. Be sure to maintain and check irrigation equipment regularly.

Nutrition management

Poor nutrition can reduce plant health and vigor even in the absence of visible deficiency symptoms. Proactive nutrition management can help to reduce the pendulum swings of fertilizing only when plants become symptomatic. Follow the old adage "Test, don't guess." Soil and foliar nutrient testing should be key components of a nutrient management plan as well as an aid in troubleshooting.

Management records

Keep records on all site visits and management operations.

Resources

Develop a reference library for easy access to books and periodicals. Maintain an up-to-date list of Internet sites related to diagnosing plant problems and treatment recommendations. Here are some references to aid in diagnosing abiotic plant problems.

- **Plant Health Care for Woody Ornamentals.** 1997. International Society of Arboriculture, Savoy, Ill.: Cooperative Extension Service, College of Agricultural, Consumer, and Environmental Science, University of Illinois, Urbana-Champaign.

- Costello, L.R., et al. 2003. **Abiotic Disorders of Landscape Plants.** Pub. 3420. University of California. Oakland, Calif.

Other publications

- **E2839:** Pocket IPM Guide for Woody Ornamental/Landscape Plants, 128pp., $15;
- **E2982:** Pocket IPM Guide for Weed Identification in Nurseries and Landscapes, 176 pp., $19.

Available from your county Extension office or the MSU Bulletin Office: **www.emdc.msue.msu.edu**

Nevertheless, weather extremes and other factors causing abiotic disorders are a fact of life. We don't need to feel completely at the mercy of Mother Nature, however. By selecting the right plants, performing thorough planning exercises and maintaining proper management techniques, we can eliminate or reduce the impact of abiotic factors on our production or landscape systems.

Photographs by Robert Schutzki and Bert Cregg, except as noted.
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