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Winter salt injury and salt-tolerant landscape plants

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Winter in Wisconsin often means snow and ice. To allow safe travel for pedestrians and motorists, walkways and roads must be kept as ice-free as possible. While snow and ice removal is best done with shovels, snow blowers, and plows, this may not remove all of the snow, and ice can quickly form, leaving slick, hazardous surfaces. Deicing salts are used extensively to melt this ice and snow.

Sodium chloride (NaCl), or rock salt, is the most commonly used deicer due to its effectiveness, availability, and comparatively low cost. However, it also has significant drawbacks. It's highly corrosive, causing significant environmental damage and corroding vehicles and concrete. The national cost of damage to vehicles and infrastructure alone is estimated at $3.5 to $7.0 billion annually.

This publication focuses on recognizing and preventing plant damage caused by deicing salts, evaluates the pros and cons of alternatives to rock salt, and provides an extensive list of salt-tolerant plants.

Types of salt damage

Soil damage. When salt accumulates in the soil, excessive sodium (Na) from salt destroys soil structure, raises soil pH, and reduces water infiltration and soil aeration, leading to soil compaction, increased erosion, and water runoff. The soil becomes unsuitable for proper root growth and plant development. Deicing salts are also detrimental to beneficial mycorrhizal fungi in the soil, which form a symbiotic relationship with roots assisting with nutrient uptake.

Plant damage. Salt is moved off the pavement and into the environment by one of two mechanisms: it may accumulate in the soil along streets or sidewalks from melted, salt-laden snow or it may become dispersed in an aerosol spray by fast-moving traffic and high winds along wet, salted roads. This dispersed salt causes significant damage to turfgrass as well as landscape and wetland plants growing near or along roadways, highways, driveways, and sidewalks. While salt runoff is typically limited to areas bordering salted roadways, salt spray can travel hundreds and even thousands of feet from the road.

Browning along the edges of these maple leaves may be indicative of salt injury.

Plant roots can take up salt, leading to accumulation in the plant. Plants may also have salt deposits on surfaces, such as twigs, buds, or leaves, causing tissue dehydration. Build-up of deicing salts in the plant can interfere with photosynthesis and other plant processes, like respiration and transpiration. Chloride (Cl) ions in salt can injure plant tissue, reduce water uptake, and cause nutrient imbalances such as magnesium (Mg) and potassium (K) within a plant. Salt applications made in late winter or early spring cause the most damage compared to applications made earlier due to active uptake of water by the root systems as plants are beginning to break their dormancy. In areas where salt concentrations are high, native vegetation is being replaced by salt-tolerant, invasive species such as reed canarygrass (*Phragmites australis*) and/or narrow-leaved cattail (*Typha angustifolia*) leading to landscapes dominated by a single species.

People. Well water contaminated with excessive chloride contributes to hypertension and other heart related conditions in humans. The intake of high chloride levels from salt may also be associated with elevated mortality from cancer. Maximum safe level of chloride in drinking water is 250 mg/L (250 ppm) but salt runoff often exceeds these levels.

Water quality. Water quality can be adversely affected by road salt runoff into lakes, ponds, rivers, and wetlands.

Wildlife. Local wildlife lose food and shelter as plants die due to excess salt.

Diagnosing salt injury

Diagnosing salt injury can be difficult because similar symptoms may result from a wide variety of causes. The following problems all cause similar symptoms: drought stress, root damage from construction, girdling roots, winter burn of foliage, air pollution, compacted soil, grade changes, nutrient deficiencies, insects and diseases, natural gas leaks, water-logged soils, and improper planting depth. There are, however, some details to look for that may help:

Indications of salt spray injury

- Salt damage more severe on side of plant facing the road or on outer portions of dense plants
- Severity of damage increases with volume and speed of traffic and amount of salt used
- Plants downwind from road show more damage than upwind
- Most damage occurs within 60 feet of road and decreases with distance from road
- Sensitive plants show symptoms of salt damage at distances as much as 1,000 feet or more from major highways
- Branches covered by snow or sheltered from road show no damage
- Branches growing above spray drift zone show no damage
- Plants that are less cold hardy show more injury

Indications of soil salt injury

- Most damage occurs within 30 feet of road and decreases with distances from road
- Plants are severely injured in poorly drained soils or where runoff from salt-laden snow collects
- Damage increases with amount of salt used
- Plants growing near areas that receive frequent salt applications (walkways, parking lots, entrances) show most damage
- Plants damaged over several years lack vigor and are in decline

If salt injury is suspected, either foliar analysis or soil salt tests are needed to confirm the diagnosis. These tests are available at a soil and plant analysis lab for a nominal fee. Collect soil samples in early spring before rain leaches salts out of the sampling area. Leaf and stem tissue samples can be submitted during the growing season for chloride content. Foliar chloride concentrations that exceed 0.5% dry weight for conifers and 1.0% for deciduous plants are considered harmful. Use clean pruners and wear gloves when handling the samples to avoid contamination of sample, or prune the tissue directly into plastic bags. Contact your county Extension office for specific instructions, location, and costs for this service.

Symptoms of salt injury

Salt spray

Salt spray enters plants through buds, bud and leaf scars, young shoots, as well as the leaves of evergreens species. Salt deposited on plants draws moisture out of the tissues causing desiccation (drying) and burn. Recent research indicates that salt spray injury contributes to winter injury, although it does not normally affect cold hardiness of dormant buds on woody ornamentals. The morphology and physiology of a plant bud appear to work together determining tissue sensitivity to deicing salts and freezing temperatures. For example, species that have naked buds (no scales on buds) appear more susceptible to freezing and to deicing salt than species with multi-scaled (covered) buds. Buds are most susceptible in late winter and early spring as they break dormancy. The degree of bud injury can be influenced by the plant's genetic differences, type of salt exposure (aerial spray or soil salt), intensity of the salt exposure, biotic factors, climate, and seasonal differences.

Salt accumulation and damage of Japanese pachysandra foliage

Symptoms on deciduous plants

- Injury appears in early spring
- Delayed budbreak
- Reduced leaf size and stem growth
- Off-colored foliage
- Outer edges of leaves turn brown
- Plants may fail to flower
- Death of buds and twigs leading to misshapen, unsightly looking plants
- When the tip of a branch dies back, many new shoots sprout just below the dead area, creating a "witches' broom"
- Crown of the tree begins to thin
- Large branches may die if severe injury occurs over several years

Symptoms on evergreens

- Injury evident in late winter to early spring
- Tips of mature needles turn brown or yellow; discoloration moves down the needle, eventually killing entire needle; damaged needles eventually fall off
- Discoloration of needles is often hidden by new growth in spring
- Twigs die back
- Symptoms occur primarily on the side of the plant facing the road

Soil salt

Unlike salt spray injury, soil salt injury is slow to develop and injury progresses over several years. Deicing salts create a wide range of problems for plants. Salt is highly absorbent and binds tightly with water, preventing plant roots from taking up water. Thus, even when soil moisture is plentiful, high salt levels create an artificial, drought-like environment for plants. Compounding the problem, high concentrations of soil salt can actually draw water out of the roots. When roots do absorb salt, high concentrations will eventually kill roots, causing plants to decline over several years. At high concentrations in the soil, sodium (Na) will compete with essential nutrients for uptake by plants. Roots will also absorb toxic levels of chloride (Cl) from deicing salts, which accumulates in buds, leaves and twigs, causing desiccation (drying). Since an affected plant's health is compromised, it become more susceptible to insects, diseases, and drought stress. With regard to soil texture, plants tend to be more salt tolerant in sandy, well-drained soils than in heavy clay soils as the salt is more easily leached through the soil by rainwater.

Symptoms on deciduous plants

- Browning along edges of leaves
- Wilting during hot, dry weather when soil moisture is limited
- Off-colored or discolored foliage
- Nutrient deficiencies, in particular magnesium and potassium
- Stunting and reduced plant vigor
- Plant produces fewer, smaller leaves that are often chlorotic (yellow)
- Premature fall coloration and leaf drop
- Flowers and fruit smaller than normal
- Twig dieback
- Turfgrass and herbaceous perennials may die due to excessive soil salt

Symptoms on evergreens

- Similar to salt spray injury, but both old and new needles are affected
- Eventual plant death

THE TIPS OF THESE EASTERN WHITE PINE NEEDLES ARE TURNING BROWN FROM SALT INJURY. DAMAGE WILL PROGRESS INWARD, EVENTUALLY KILLING THE NEEDLES.

EASTERN WHITE PINE TREES DAMAGED ON SIDE OF TREE FACING THE ROAD. NOTE SALT DAMAGE DID NOT OCCUR ON LOWER FOLIAGE DUE TO SNOW COVER.

Prevention of Salt Injury

There are many ways to prevent or alleviate salt injury. Deicing salt applications should be used primarily in high-risk areas such as highways, intersections, hills, steps, and major walkways; limit applications in non-critical areas. If possible, avoid using pure sodium chloride (NaCl), a common deicing salt. Instead, mix less than 5% of sodium chloride (NaCl) with abrasive materials such as sand, crushed rock, kitty litter, ash or cinders, or use an alternate deicing product (see table 2 for a comparison of available products). These mixtures are particularly useful on roads with low traffic volume and when temperatures fall below 20°F (sodium chloride is ineffective at colder temperatures). For example, 1 pound of deicing salt mixed with 50 pounds of sand makes an effective abrasive compound, particularly on walkways where good foot traction is required. This combination stays loose and unfrozen and is easy to spread; however, there is usually not enough salt to do any appreciable melting. Do not use commercial fertilizers as a deicing salt as these products will burn plant roots.

If using a deicer, wait to apply until after all the snow has been plowed or shoveled. Early applications of small amounts of salt can be very effective in keeping ice from bonding to the pavement, which improves removal of snow and ice after a storm. Remove slush before it has a chance to refreeze. Once ice has bonded to the pavement, it takes more salt to remove the ice than if a lighter application been made earlier. If possible, avoid application of salt in late winter and early spring as the plants are coming out of dormancy.

Prevention Tips

- One of the best preventive techniques is to plant salt-tolerant species in areas that are subject to salt spray or runoff (see table 1). Be aware that a plant's degree of tolerance to soil salts may be different from its aerial salt tolerance.
- In areas where soil salt is a problem, planting trees and shrubs on berms (raised, mounded beds) will prevent salty runoff water from moving into root zones.
- Protect plants from salt spray by placing physical barriers such as plastic, burlap, or snow fencing around or near plants in late fall.
- Avoid shoveling salt-laden snow over the root zones of sensitive plants.
- During a warm spell in winter, rinse off plants to eliminate residual salt before budbreak.
- In early spring, water soil heavily (at least 6 inches) to flush salt out of the plant's root zone.
- Direct salt runoff away from plants using barriers such as gutters or alter drainage patterns away from planting areas. (This method works best on well-drained soils and is not very effective on clay soils and compacted soils where water does not drain readily.)
- Application of gypsum ($CaSO_4$) to heavy clay soils that are high in salt will displace the sodium ion with calcium, improving both aeration and drainage.
- If salt-sensitive plants are to be used, plant them at least 60–100 feet from highways and 30–40 feet from city streets where salt runoff into soil is common.

Use of anti-transpirants and dormant oil sprays are ineffective in prevention of salt spray injury and are not recommended.

ON DECIDUOUS TREES, CLUSTERS OF NEW SHOOTS, KNOWN AS "WITCHES' BROOMS," SPROUT WHERE BRANCH TIPS DIE BACK.

Why some plants are salt tolerant

A variety of physiological characteristics are involved in making plants tolerant or susceptible to salt.

Protection against salt spray. Some plants have features that physically prevent salt spray from penetrating. Such features include hidden or submerged buds; thick surface wax; numerous, tightly arranged bud scales; fuzzy buds; or sticky resin-coated buds. (None of these structures protect the plant against soil-borne salt, which is taken up through the roots.) In contrast, plants that produce naked buds (no bud scales) are very susceptible to salt spray injury in winter, more so than plants with scaled buds. Examples of plants that have naked buds include wayfaringtree viburnum (*Viburnum lantana*), Koreanspice viburnum (*Viburnum carlesii*), Judd viburnum (*Viburnum* x *juddii*), pawpaw (*Asimina triloba*), witchhazels (*Hamamelis* spp.), fothergillas (*Fothergilla* spp.), and the highly invasive tallhedge buckthorn (*Rhamnus frangula* 'Columnaris').

Protection against soil salt. Some plants, such as green ash (*Fraxinus pennsylvanica*), are able to exclude soil salt from entering their cells or they may be able to withstand higher concentrations within the cells.

Varying degrees of tolerance. An individual plant's tolerance to salt will vary depending on its state of dormancy, on temperature fluctuations, and on morphological changes. Plants exhibit the greatest resistance to salt damage in early winter (December through early January). In March and April as spring approaches, buds become much more susceptible to salt injury. Newly planted trees and shrubs, which have small root systems and little stored water, are more susceptible to salt injury in winter than established plants. For these plants, extra attention should be given to preventive measures during the first few years after planting to help protect plants from salt damage.

Products for ice control and alternatives

There are several chemicals commonly used as deicers. They are often blended together or combined with other materials such as sand, cinders, ash, agricultural byproducts, or other proprietary material to improve performance, limit environmental and concrete damage, and reduce cost. There are many commercial blends available in local stores with different percentages of deicing chemicals. Some deicing compounds are sold with anti-corrosive additives. While additives help, they will not eliminate corrosion entirely and their effects on plants and the environment are often unknown.

Performance of a deicing product is influenced by many factors including chemical concentration, air and pavement temperatures, traffic and weather conditions, type of road surface, topography, traffic volume, width of application, duration of the deicing salt melting action, shape of the deicer particles, and the time it takes the deicing salt to form a brine. Consider a balance between safety, cost, and practical storage and application issues when selecting a final product to use.

Always follow label directions when using a deicing product. Never over-apply deicing products as this may cause serious damage to plants and the environment.

Table 1. Salt-tolerant landscape plants

SPRAY	SOIL	Deciduous trees		ZONE
H		*Acer campestre*	Hedge maple	5b
H		*Acer miyabei*	Miyabe maple	4a
H		*Acer platanoides*	Norway maple	4b
H		*Acer pseudoplatanus*	Sycamore maple	5b
M		*Acer tataricum* subsp. *ginnala*	Amur maple	3a
H		*Aesculus* x *carnea*	Red horsechestnut	5a
H	M	*Aesculus hippocastanum*	Common horsechestnut	4b
M		*Amelanchier* x *grandiflora*	Apple serviceberry	3a
M		*Betula nigra*	River birch	4a
H		*Carya ovata*	Shagbark hickory	4b
M	M	*Catalpa speciosa*	Northern catalpa	4a
H	M	*Crataegus crus-galli*	Cockspur hawthorn	4a
H	H	*Fraxinus americana**	White ash	4a
H		*Fraxinus excelsior**	European ash	4b
H	H	*Fraxinus pennsylvanica**	Green ash	2a
M		*Fraxinus quadrangulata**	Blue ash	4a
M	M	*Ginkgo biloba*	Ginkgo	4b
H	H	*Gleditsia triacanthos* var. *inermis*	Thornless honeylocust	4a
H	H	*Gymnocladus dioicus*	Kentucky coffeetree	4a
H		*Juglans nigra*	Black walnut	4b
H		*Larix decidua*	European larch	3a
H		*Larix kaempferi*	Japanese larch	4a
H		*Larix laricina*	American larch, tamarack	2a
H	H	*Liquidambar styraciflua*	Sweet gum	5b
M	M	*Nyssa sylvatica*	Black gum, tupelo, sour-gum	4b
H		*Populus deltoides*	Eastern cottonwood	3a
H		*Populus grandidentata*	Bigtoothed aspen	3a
H		*Populus tremula* 'Erecta'	Upright European aspen	2b
H		*Populus tremuloides*	Quaking aspen	2a
H		*Prunus americana*	American plum	3b
M		*Prunus maackii*	Amur chokecherry	3a
M		*Prunus sargentii*	Sargent cherry	4b
M	M	*Prunus virginiana*	Chokecherry	3a
M		*Pyrus calleryana*	Callery pear	4b
M		*Quercus alba*	White oak	3b
M	M	*Quercus bicolor*	Swamp white oak	4a
M	M	*Quercus ellipsoidalis*	Northern pin oak	4a
M		*Quercus imbricaria*	Shingle oak	4b
M	M	*Quercus macrocarpa*	Bur oak	3a
M		*Quercus robur*	English oak	5a
M	M	*Quercus rubra*	Northern red oak	3b
H		*Robinia pseudoacacia* 'Lace Lady'	Twisty Baby® black locust (fruitless)	4b
H		*Salix matsudana* 'Tortuosa'	Curly willow, contorted willow	4b
H		*Salix* x *sepulcralis* var. *chrysocoma*	Golden weeping willow	4a
H		*Styphnolobium japonicum*	Japanese pagodatree	5b
H	H	*Syringa pekinensis*	Peking lilac or Pekin lilac	4a
H	H	*Syringa reticulata*	Japanese tree lilac	3a
H	M	*Taxodium distichum*	Baldcypress	4b
H		*Ulmus glabra*	Scotch elm	4b
H	M	*Ulmus* hybrids	Hybrid elms	4a-5
		Deciduous shrubs		
M		*Amelanchier canadensis*	Juneberry, serviceberry	3b
H	H	*Amorpha fruticosa*	Indigo-bush	4b
M		*Aronia arbutifolia*	Red chokeberry	4b
M		*Aronia melanocarpa*	Black chokeberry	3b
H		*Berberis koreana*	Korean barberry	4a
H		*Berberis thunbergii*	Japanese barberry	4a
	H	*Buddleja davidii*	Butterfly bush (dieback shrub)	5b
H	H	*Caragana arborescens*	Siberian peashrub	2a
M		*Clethra alnifolia*	Summersweet clethra	4b
H		*Comptonia peregrina*	Sweet-fern	3b
M	M	*Cotoneaster apiculatus*	Cranberry cotoneaster	4b
M	M	*Cotoneaster divaricatus*	Spreading cotoneaster	5b
M	M	*Cotoneaster horizontalis*	Rockspray cotoneaster	5a
M	M	*Cotoneaster acutifolius* var. *lucidus*	Hedge cotoneaster	3a
M		*Cotoneaster multiflorus*	Many-flowered cotoneaster	4b
H		*Euonymus alatus*	Winged euonymus, burningbush	4a-b
H	H	*Hippophae rhamnoides* 'Sprite'	Sprite common seabuckthorn	4a

*No longer recommending planting ash (*Fraxinus* spp.) species due to susceptibility to Emerald ash borer

(H = high level of tolerance; M = moderate level of tolerance)

SPRAY	SOIL	DECIDUOUS SHRUBS		ZONE
H		*Hydrangea macrophylla*	Bigleaf hydrangea	5a-6
H		*Hypericum kalmianum*	Kalm's St. Johnswort	4a
M		*Ilex verticillata*	Winterberry, Michigan holly	3b
	H	*Lespedeza bicolor*	Shrub bush-clover (dieback shrub)	5b
M	H	*Morella pennsylvanica (Myrica pennsylvanica)*	Northern bayberry	4a
	H	*Perovskia atriplicifolia*	Russian sage (dieback shrub)	5a
M		*Philadelphus coronarius*	Mockorange	4b
H		*Dasiphora fruticosa (Potentilla fruticosa)*	Potentilla	3a
H		*Prunus maritima*	Beach plum	3b
H		*Pyracantha coccinea*	Scarlet firethorn	5b
H		*Rhodotypos scandens*	Black jetbead	5a
H	H	*Rhus aromatica*	Fragrant sumac	3b
H	H	*Rhus copallina*	Shining sumac, winged sumac	4b
H	H	*Rhus glabra*	Smooth sumac	3a
H	H	*Rhus typhina*	Staghorn sumac	3b
M	H	*Ribes alpinum*	Alpine currant	3a
H		*Ribes odoratum*	Clove currant	4a
H	H	*Robinia hispida*	Bristly locust (fruitless)	5b
H	H	*Rosa rugosa*	Rugosa rose	2b
H		*Rosa virginiana*	Virginia rose	3b
H		*Salix caprea*	Goat willow	4a
H		*Salix discolor*	Pussy willow	3a
H		*Salix purpurea*	Purpleosier willow, blue arctic willow	3b
H		*Shepherdia argentea*	Silver buffaloberry	3a
M		*Spiraea japonica*	Japanese spirea	3b
M		*Spiraea nipponica* 'Snowmound'	Snowmound spirea	4a
M		*Spiraea* x *vanhouttei*	Vanhoutte spirea	4a
H		*Symphoricarpos albus*	Common snowberry	3b
M	M	*Syringa meyeri* 'Palibin'	Palibin lilac	4a
M	M	*Syringa pubescens* subsp. *patula* 'Miss Kim'	Miss Kim lilac	3b
H		*Tamarix chinensis*	Tamarisk	2b
M		*Viburnum dentatum*	Arrowwood viburnum	4a

SPRAY	SOIL	DECIDUOUS SHRUBS		ZONE
M		*Viburnum lentago*	Nannyberry viburnum	3a
M	M	*Viburnum prunifolium*	Blackhaw viburnum	4a
M		*Viburnum opulus* var. *americanum* (*Viburnum trilobum*)	American cranberrybush viburnum	3a
	H	*Vitex agnus-castus*	Chastetree (dieback shrub)	5b
H		*Yucca filamentosa*	Adam's needle yucca	4b
H		*Yucca filifera* 'Golden Sword'	Golden sword yucca	4b
		EVERGREEN TREES & SHRUBS		
M		*Juniperus chinensis*	Chinese juniper	4a
H	H	*Juniperus communis*	Common juniper	3a
H	H	*Juniperus communis* var. *depressa*	Common oldfield juniper	3a
H	H	*Juniperus virginiana*	Eastern red-cedar	3b
H	M	*Picea pungens* var. *glauca*	Colorado blue spruce	3a
H		*Pinus banksiana*	Jack pine	2a
H		*Pinus leucodermis*	Bosnian pine	4b
H	H	*Pinus mugo*	Mugo pine	3a
H		*Pinus nigra*	Austrian pine	4a
H		*Pinus parviflora*	Japanese white pine	5a
H		*Pinus ponderosa*	Ponderosa pine	4a
H		*Pinus sylvestris*	Scots or scotch pine	3a
		GROUNDCOVERS		
H		*Arctostaphylos uva-ursi*	Bearberry	2b
H		*Euonymus fortunei* 'Coloratus'	Purpleleaf wintercreeper	4b
H		*Hedera helix*	English ivy	4b
H	H	*Juniperus horizontalis*	Creeping juniper	3a
H	H	*Juniperus sabina*	Savin juniper	3a
H	H	*Juniperus sargentii*	Sargent juniper	4a
H		*Prunus pumila* var. *depressa*	Eastern sandcherry (deciduous)	4b
H	H	*Rhus aromatica* 'Gro-low'	Gro-Low sumac (deciduous)	3b
		VINES		
H		*Campsis radicans*	Trumpetcreeper	4b
H		*Hedera helix*	English ivy	4b
H		*Parthenocissus inserta*	Woodbine	3b
H		*Parthenocissus quinquefolia*	Virginia creeper	3b

SPRAY	SOIL	ORNAMENTAL GRASSES		ZONE
	H	*Calamagrostis* x *acutiflora* 'Karl Foerster'	Karl Foerster feather reed grass	4b
	H	*Chasmanthium latifolium*	Northern sea oats	4b
	M	*Festuca glauca* 'Elijah Blue'	Elijah Blue fescue	4a
	M	*Helictotrichon sempervirens*	Blue oat grass	4a
	H	*Leymus arenarius* 'Glaucus'	Blue lyme grass	4a
	M	*Miscanthus* spp.	Miscanthus, maiden grass	5a
	H	*Panicum virgatum*	Switch grass	4b
	H	*Pennisetum alopecuroides*	Fountain grass, pennisetum	5a
	M	*Schizachyrium scoparium*	Little bluestem	4a
		HERBACEOUS PLANTS		
	M	*Achillea millefolium* 'Apple Blossom'	Apple Blossom common yarrow	3b
	M	*Achillea* 'Moonshine'	Moonshine yarrow	3b
	H	*Allium christophii*	Stars of Persia	4b
	H	*Allium senescens*	Ornamental onion	3b
	H	*Anthemis punctata* subsp. *cupaniana*	Anthemis	5b
	H	*Armeria maritima* 'Splendens'	Splendens sea thrift	4a
	M	*Artemisia ludoviciana*	White sage	4a
	M	*Artemisia* 'Powis Castle'	Powis Castle artemisia	5b
	M	*Artemisia schmidtiana* 'Nana'	Dwarf silvermound artemisia	3b
	M	*Artemisia stelleriana*	Beach wormwood	4a
	M	*Aster novae-angliae* 'Purple Dome'	Purple Dome New England aster	4a
	M	*Bergenia cordifolia*	Heart-leaf bergenia	3b
	M	*Catananche caerulea*	Cupid's dart	4b
	M	*Centranthus ruber*	Jupiter's beard, red valerian	5a
	H	*Crambe maritima*	Sea kale	5a
	H	*Dianthus* x *allwoodii* 'Helen'	Helen allwood pinks	4a
	M	*Dianthus gratianopolitanus*	Cheddar pinks	4a
	H	*Echinops* spp.	Globe thistle	4a
	H	*Erigeron glaucus*	Seaside aster, beech fleabane	4a
	H	*Eryngium* x *oliverianum*	Sea holly	4a

SPRAY	SOIL	HERBACEOUS PLANTS		ZONE
	H	*Eryngium* x *tripartitum*	Sea holly	5b
	M	*Euphorbia polychroma*	Cushion spurge	4a
	M	*Gaillardia* x *grandiflora* 'Goblin'	Goblin blanket flower	3a
	M	*Goniolimon tataricum*	German statice	4b
	M	*Gypsophila paniculata*	Baby's-breath	4a
	M	*Hemerocallis* spp.	Daylily	3b
	M	*Heuchera micrantha* 'Palace Purple'	Palace Purple coral bells	4a
	M	*Heuchera sanguinea* 'Chatterbox'	Chatterbox coral bells	4a
	M	*Hosta plantaginea*	Fragrant hosta, August lily	4a
	M	*Hosta undulata* 'Medio-variegata'	Variegated hosta, wavy hosta	3b
	M	*Iberis sempervirens*	Evergreen candytuft	5a
	M	*Iris sibirica* 'Caesar's Brother'	Caesar's Brother Siberian iris	3b
	M	*Iris* spp. (Germanica Group)	Bearded iris	3b
	M	*Kniphofia* 'Royal Standard'	Red-hot poker	5b-6
	M	*Leucanthemum* x *superbum* 'Becky'	Becky shasta daisy	4a
	M	*Limonium latifolium*	Purple sea lavender	4a
	M	*Liriope spicata*	Creeping lilyturf	5b
	M	*Nepeta* x *faassenii*	Nepeta, catmint	4a
	M	*Oenothera fruticosa* subsp. *glauca*	Sundrops	4a
	M	*Oenothera macrocarpa*	Silver evening primrose	4a
	M	*Penstemon* spp.	Beardtongue	3b-4a
M	M	*Phlox subulata*	Creeping phlox (evergreen)	4a
	M	*Physostegia virginiana*	Obedient plant	3a
	M	*Saponaria ocymoides*	Rock soapwort	4a
	M	*Sedum* spp.	Stonecrop	3b-4
	M	*Sedum* 'Herbstfreude'	Autumn Joy sedum	3b
	M	*Sempervivum* spp.	Hens and chicks	4a
	M	*Sidalcea malviflora*	Prairie mallow	4b
	M	*Thymus* spp.	Thyme	5b
	M	*Veronica incana*	Woolly speedwell	3b
	M	*Waldsteinia ternata*	Barren strawberry	3b

(H = HIGH LEVEL OF TOLERANCE; M = MODERATE LEVEL OF TOLERANCE)

TABLE 2. Products available for ice control (not including products used only in airports)

PRODUCT	ADVANTAGES	DISADVANTAGES
SODIUM CHLORIDE (NaCl)	• Effective, melts snow, penetrates ice • Low cost • Dissolves easily • Readily available • Easy to remove residue from floors and carpets	• Highly corrosive • Accumulates in soil • Damages soil structure • Injurious to plants • Readily leaches and contaminates groundwater • Increases runoff of heavy metals • Increases soil erosion • Ineffective at temperatures below 20°F
CALCIUM CHLORIDE ($CaCl_2$)	• Effective to –20°F • Works better at lower temperatures than NaCl • Dissolves faster than NaCl at lower temperatures • Releases some heat when dissolved • Won't damage soil structure • Often included in commercial blended products • No visible residue on plants when dry	• Highly corrosive, but anti-corrosive compounds can be added • Costs about 10 times more than NaCl • Injurious to plants • Readily leaches into groundwater • Requires special storage and handling to prevent caking • Tends to keep pavement wet • Leaves greasy stains on carpets and dulls floors from shoes • Causes skin irritation—must wear protective clothing when applying • Damages leather gloves and shoes
MAGNESIUM CHLORIDE ($MgCl_2$)	• Effective to 0°F • Dissolves easily and faster acting than NaCl • Works better at lower temperatures than NaCl • Won't damage soil structure • Available with corrosion inhibitors	• Highly corrosive, but anti-corrosive compounds can be added • Costs about 10 times more than NaCl • Injurious to plants • Readily leaches into groundwater • Requires special storage and handling to prevent caking • Tends to keep pavement wet • Leaves greasy stains on carpets and dulls floors from shoes
POTASSIUM CHLORIDE (KCl)	• Used as a commercial fertilizer • Dissolves easily • Won't damage soil structure • Easy to handle and store • Easy to remove residue from floors and carpets	• Highly corrosive • Costs about 10 times more than NaCl • High salt index and potential to burn foliage and roots • Readily leaches into groundwater • Limited use • Ineffective at temperatures below 25°F
POTASSIUM ACETATE (K-acetate)	• Produced from renewable resources • Effective to –25°F • Biodegradable • Safe for the environment and plants • Non-corrosive • Won't damage soil structure • More desirable than urea or glycol for airport application	• Very expensive • Only available as a liquid; requires liquid application equipment • Not commonly available

TABLE 2. Products available for ice control (not including products used only in airports), *continued*

PRODUCT	ADVANTAGES	DISADVANTAGES
UREA OR NITROGEN SALTS SUCH AS AMMONIUM SULFATE [$(NH_4)_2SO_4$], or **POTASSIUM NITRATE** (KNO_3)	• Used as a commercial fertilizer • Lower burn potential than KCl • Less damaging to plants than NaCl • Melts snow, but not commonly used • Non-corrosive (if use lower ammonia content)	• May be corrosive if using high ammonia content • Expensive • May cause concrete degradation • Reduced effectiveness below 25°F • High potential for nitrogen runoff to surface water • Runoff promotes weed growth and eutrophication of lakes • Readily leaches into groundwater • Toxic to fish and animals
CALCIUM MAGNESIUM ACETATE (CMA)	• Made from dolomitic limestone and acetic acid • Biodegradable • Does not harm plants • Won't damage soil structure • Can increase soil permeability • Adds calcium and magnesium to soil • Less corrosive than other deicing salts • Less likely to leach into groundwater • Can be used in environmentally sensitive areas • Does not bond to pavement, so snowplow can scrape aside dry snow	• Costs approximately 40 times more than NaCl • Ineffective at temperatures below 20°F, in freezing rain, and on dry snow • Poor at removing existing ice • Can leach into surface water (lakes and ponds), degrading water quality • Leaves a slight greasy film on carpets
AGRICULTURAL BY-PRODUCTS from processing of sugar beets or processed corn or by-products from beer brewing. Product can be used as a pre-wetting liquid for deicing salts, or as a component of a liquid deicing salt brine solution.	• Non-corrosive and reduces corrosiveness when mixed with chloride-containing deicers • Increases equipment life • Reduces deicing salt consumption and labor costs • Less harmful to plants as less deicing salt is needed • Biodegradable (before mixed with deicers) • Adheres well to dry surfaces thereby preventing ice and snow from sticking to pavement • Mixes well with other liquid chemicals • Improves ice melting of chloride-containing deicers when mixed with it • Greater low temperature performance when mixed with deicers • No dust-causing abrasives are needed	• Expensive and adds cost to chemical deicing mixtures • Only available as a liquid • Purity of product and amount of smell varies between agricultural by-products used • May contain high phosphates (depends on product) • Very sticky material that can track under foot and vehicle traffic • Some blends may have high biological oxygen demand* and could remove oxygen from surface waters if not fully biodegraded before entering surface water

*Biological oxygen demand is a measurement of the oxygen consumed by microorganisms decomposing organic matter in water. This would primarily be a concern in ponds and lakes.

TABLE 2. Products available for ice control (not including products used only in airports), *continued*

PRODUCT	ADVANTAGES	DISADVANTAGES
ABRASIVE MATERIALS (sand, crushed aggregate, slag, bottom ash, kitty litter, cinders)	• Low initial cost • Readily available • Does not harm plants • Non-corrosive • Useful at lower temperatures when deicing chemicals become less effective • Improves traction for vehicles and pedestrians • Works immediately upon application	• Does not melt ice or snow • Traffic reduces its effectiveness (blown off, pushed off into snow) • Covered by new snow • Does not work well on hard ice • Not as effective as deicing salts at preventing skids • Requires reapplication, leading to more equipment trips per mile than NaCl • Accumulates and clogs gutters and drains; must be removed • Can chip paint and scar windshields if kicked up by traffic • Some abrasives create dust problems after storms and can contribute to particulate air pollution (ash fines)

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