SELECTION OF TREES FOR TOLERANCE TO SALT INJURY[1]

by Michael A. Dirr

Abstract: No plants are wholly immune to salt injury and this should be considered before any type of breeding-screening-selection process is initiated. Salinity, like other stressful features of the environment, results in the evolution of races, or ecotypes adapted to it. The possibility of breeding salt tolerance into plants exists, but the strategy has not been tried in any sustained energetic manner. Salt usage, especially deicing, is increasing yearly. Plants growing along highways, on lawns, and along sidewalks exhibit stem dieback, and many are killed. The salts are deposited as spray on buds, stems, and leaves or are accumulated in the root zone. Subsequent injury results from osmotic and/or specific ion effects. Evaluations of salt-induced injury should be based on salts, concentrations, application methods, osmotic effects, shoot or leaf contents of Cl, and perhaps, shoot levels of Na. The appearance of the plant is not always reflective of the salt-induced damage, and growth parameters should be used to augment visual evaluations.

A logical question which one should ask before engaging in a long term breeding-screening-selection process is whether plants possess the genetic complement which would result in the manifestation of anatomical, morphological, and/or biochemical features which lend salt tolerance. Epstein (8) noted that like other stressful features of the mineral environment, salinity often results in the evolution of races, or ecotypes adapted it. The possibility of breeding salt tolerance into plants exists, but the strategy has not been tried in any sustained energetic manner (4). Gold (10) emphasized that plant species must be selected for tolerance to urban conditions, and the conditions he included were drought, poor aeration, compaction, mineral deficiencies, contamination by *salts*, heavy metals and pesticides, air pollution, and mechanical impacts by man. Smith (29) reported that salts ranked second to air pollution as a negative cultural factor affecting woody plant growth in northern metropolitan areas. He based this ranking on the results of a questionnaire which was sent to individuals in the arboricultural professions. Eighty-seven percent of those responding considered air pollution significant while 86 percent thought salts were serious. However, studies related to the effects of salts on woody plant growth have received minimal time and money compared to air pollutant effects.

One of the governing principals for a breeding-screening-selection process should take into account that no plants are wholly immune to salt injury (14). Even the most halophytic (salt-tolerant) plants do not thrive under highly saline conditions. At best plants may tolerate, strategically avoid, or otherwise cope with salinity, but usually they grow better under conditions of low salinity (26). The aim of any program should be to select plants for partial resistance and not total immunity. The sources of salts, whether they are derived from the ocean, highway deicing, or saline soils, are not important. The detrimental effects from these salts on woody plant growth are manifested in essentially similar ways. This paper is largely restricted to highway deicing salts and their relationships to woody plant growth and development.

Westing (30) estimated that approximately 12 million tons of salt are applied to northeastern highways per year. More specifically, state-maintained Illinois highways received 300,000 tons (272,727 metric tons) during the winter of 1969-70 and Chicago freeways received 18 percent of this total. In severe winters Chicago freeways have received as much as 80 tons per lane mile (45 metric tons per lane Km). Fifteen to 25 tons per two-lane mile (8 to 14 metric tons per Km) were common in several New England states. In Maine, Langille (19) noted that between 22 to 29.7 tons (20 to 27 metric tons) are applied per two-lane mile of highway. Salts are important pollutants and will continue to increase as highways increase, and as the motoring public continues to demand safe driving conditions. Deicing salts pre-

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sent an unusual but significant cultural problem; one to which there are few logical alternatives. The two principal deicing salts are sodium chloride (NaCl) and calcium chloride ($CaCl_2$); the former being used in a ratio of 19:1 over the latter.

Plants are injured by salts that are deposited as spray drift on dormant stems and buds of deciduous trees, and on stems, buds, and leaves of evergreens; by excess amounts of salts that leach into the root zone; or by a combination of the two. Most woody plant injury is induced by the first mentioned mode of deposition (3,7,11,21), although some injury has been attributed to salt accumulation in the soil (3,15). The soluble salt content (16) of soils along Chicago freeways varies considerably, and concentrations of 20,000 ppm (2 percent) were found in sparsely vegetated areas and up to 50,000 ppm (5 percent) in denuded soil from the medians. However, these high salt soils represent only a small percentage (less than 2 percent) of the total area, and the average soil would fall in the range 500 to 2,000 ppm, which presents no problem to woody plant growth (27).

The resultant plant injury from soil salts may be caused by differences in osmotic potentials between the plant and the soil solution; by a specific ion effect usually related to the Na and Cl ions, or a combination of the two (8). Injury through osmotic effects results when the osmotic potential of the soil solution is significantly lower than that of the plant cells. Water does not move into the plant and could even move osmotically from the cells into the soil solution. Another interesting explanation for osmotic injury (24) is that salts which are absorbed by roots or through the aerial plant parts move into the outer spaces (vessels, cell wall areas) of leaf mesophyll cells. The osmotic potential of the extracellular solution may be low enough to cause an intracellular water deficit. This in turn could lead to the death of cells, especially those around the margins of the leaves.

Plant injury by deicing salts is manifested in many different ways, but the consistency, intensity, and magnitude of injury can only be accounted through the mode of aerial deposition. Lumis and others (20,21) have accurately chronicled the visual symptoms associated with salt injury. General injury patterns include:

1. Injury is more severe on the side facing the road; plants are one-sided due to branch dieback and often exhibit a "witches-broom" appearance (Figures 1 and 2).

Figure 1. Hawthorn showing typical one-sided effect due to aerial deicing salts. Note fruit on the side away from the highway and the extensive "brooming" on the side closest.

Figure 2. "Witches Broom" on hawthorn caused by dieback of the terminal and the subsequent development of many lateral branches beneath the dead area.

2. Damage is more pronounced on the down-wind side of the highway.
3. Plants farther from the road are injured less.
4. Branches that were covered by snow are not injured.
5. Injury to evergreens becomes apparent

in late winter; injury to deciduous plants is not evident until spring.

6. Branches above the spray-drift zone are not injured or are injured less.
7. Damage increases with the volume and speed of traffic and the amount of salt applied to highways.
8. Plants damaged over several years lack vigor and soon begin to die.
9. Less winter-hardy plants are injured more severely.
10. Salt spray penetrates only a short distance into dense plants.
11. Plants in sheltered locations lack injury symptoms.

Plant injury was evident as far as 150 to 200' from the highway's edge along Chicago freeways. Langille reported Na was significantly increased to distances of 50 feet from the highway's edge after one salting season while soil Cl was increased to a distance of 200 feet. Sodium and Cl significantly increased to distances of 200 feet in *Tsuga canadensis* (L.) Carr, Canadian hemlock, needles after one winter. Williams and Moser (31) have shown that regardless of the rate of deposition, plants will be injured if exposure time is sufficient and that uptake of Na and Cl is linear with time (Figure 3). When tissue Cl levels reached approximately 2.7 percent, visual injury was manifested. Their work indicated that whether plants receive salts in low levels or high levels they will exhibit injury symptoms when the tissue Na or Cl concentrations reach a threshold level.

Figure 3. Crabapple showing extensive tip dieback.

The Na and Cl ions are the two agents which must be considered in judging injury to woody plants. Sodium can replace essential cations (especially Ca) on the soil colloids and at the same time deflocculate the soil. The reduction in flocculation (loss of granulation) results in a puddled soil which lacks good drainage and proper oxygen concentrations. Chloride is a negatively charged ion and, unlike Na, is only briefly available in the root zone, especially in areas of high rainfall.

When Na and Cl ions are aerially deposited on plants, they usually penetrate the stems, buds, and leaves. Lumis and others (21) noted that although the basis for plant resistance to salt spray is not known, increased amounts of wax (bloom) on spruce needles added to their protection, because the bluer the spruce the more resistant it was to salt spray.

Several plant taxa possess highly specialized salt-secreting glands (26). These specialized structures aid in removing excess salts from the tissues. They are common in the families Plumbaginaceae and Frankeniaceae but only occur in a few scattered species outside these families. The only plant type which possesses salt glands and could be used in the northern states is *Tamarix*.

Deciduous trees and shrubs having resinous buds or buds partially embedded in the stem are resistant, while plants with naked buds are susceptible to salt spray. Dirr (5) speculated that the salt tolerance of *Gleditsia triacanthos* L. *inermis* Willd., thornless common honeylocust (one of the most salt tolerant plants, see Table 1), was attributable to the inability of Na and Cl to penetrate the waxy branches and protected buds of dormant trees. However, honeylocust seedlings grown under controlled conditions where NaCl and potassium chloride (KCl) were soil-applied showed severe injury. Total soil-soluble salts were not responsible for injury, and tissue Na had no adverse effect on growth, although Na levels of shoots were greater than 2 percent of dry weight. Shoot content of Cl was a reliable index of the degree of salt injury, because the greater the tissue amount of Cl, the more rapid was the onset and the more severe the injury.

Table 1. Relative salt tolerance of trees.

[By authors: **(1)** Buschbom (2), **(2)** Carpenter (3), **(3)** Dirr (5,6,7), **(4)** Hanes, et al (12), **(5)** Lumis, et al (20,21), **(6)** Monk and Wiebe (22,23), **(7)** Pellett (25), **(8)** Shortle and Rich (28), and **(9)** Wyman (32,33).]

	Salt-tolerance rating		
Species	Good	Moderate	Poor
Abies balsamea	—	1	7
Acer campestre	1	6	—
Acer ginnala	—	—	1
Acer negundo	—	1,7	5
Acer platanoides	1,3,5,9	7	—
Acer pseudoplatanus	9	—	2
Acer rubrum	—	5	2,7,8
Acer saccharinum	1	5	7
Acer saccharum	5	—	2,7,8
Acer tataricum	—	—	1
Aesculus hippocastanum	1,5,9	—	—
Ailanthus altissima	5,9	—	—
Alnus glutinosa	—	—	1,2
Alnus incana	—	—	7
Alnus rugosa	—	1,5	2,8
Amelanchier canadensis	9	—	—
Amelanchier laevis	—	—	5
Amelanchier species	—	—	1
Betula alleghenlensis	8	—	—
Betula lenta	8	—	—
Betula papyrifera	8	5,7	—
Betula pendula	—	1,7	—
Betula populifolia	8	5	—
Betula species	—	2	—
Caragana arborescens	1,5	—	—
Carpinus betulus	—	—	1,2
Carpinus caroliniana	—	—	7,8
Carya ovata	5	—	8
Carya species	—	—	7
Catalpa speciosa	—	5	—
Celtis occidentalis	—	—	1
Cercis canadensis	—	—	3
Chamaecyparis pisifera	—	—	1
Corylus species	—	—	1,2
Crataegus crusgalli	9	—	1
Crataegus species	—	—	1,5
Elaeagnus angustifolia	1,3,5,6,7,9	—	—
Euonymus (tree species)	—	—	1
Fagus grandifolia	—	2	1,5,7
Fagus sylvatica	—	—	1,2,7
Fraxinus americana	8	5,7	—
Fraxinus excelsior	1	—	—
Fraxinus pennsylvanica	6	2,7	—
Gleditsia triacanthos inermis	2,3,5,7	—	1
Hippophae rhamnoides	1,9	—	—
Juglans nigra	5	—	2,7
Juglans regia	5	—	2,7
Juniperus virginiana	8,9	2,7	—
Ilex opaca	9	—	—
Larix decidua	1	—	—
Larix laricina	5	—	—
Larix leptolepis	1	—	—
Larix species	—	—	2,7
Liriodendron tulipifera	—	—	4
Magnolia grandiflora	9	—	—
Malus baccata	—	2,7	—
Malus species & cultivars	—	3,5	6
Metasequoia glyptostroboides	—	—	1
Morus alba	2,6,7,9	—	5
Nyssa sylvatica	9	—	—
Picea abies	—	5,7	1
Picea asperata	9	—	—
Picea glauca	—	2	5
Picea pungens	5	—	—
Picea pungens glauca	5,9	2	—
Pinus banksiana	5	—	—
Pinus cembra	1	—	—
Pinus mugo	5	—	—
Pinus nigra	5,9	—	—
Pinus ponderosa	—	2	—
Pinus resinosa	—	—	5,7,8
Pinus rigida	9	—	—
Pinus strobus	—	—	5,7,8
Pinus sylvestris	9	7	1,3
Pinus thunbergii	9	—	—
Platanus x *hybrida*	—	—	1
Populus alba	1,2,3,7,9	—	—
Popular alba 'Pyramidalis'	3	—	—
Populus angustifolia	2	—	—
Populus deltoides	5	2	—
Populus grandidentata	8	5	—
Populus nigra 'Italica'	—	5	2,7
Populus tremuloides	8	1,2,5	—
Populus species	—	5	—
Prunus armeniaca	2,6	—	—
Prunus avium	—	1	—
Prunus padus	1	—	—
Prunus serotina	8,9	—	1
Prunus virginiana	5	—	—
Pseudotsuga menziesii	—	1,2	7
Pyrus species	—	5	—
Quercus alba	2,3,6,7,8,9	—	1
Quercus bicolor	—	—	1
Quercus macrocarpa	7	1	5
Quercus marilandica	9	—	—
Quercus muhlenbergii	—	—	1
Quercus palustris	—	—	1
Quercus robur	2,6	—	1
Quercus rubra	2,5,7,8	—	—
Rhamnus cathartica	3,5,9	—	—
Rhamnus davurica	1	—	—
Rhamnus frangula	3	5	—
Rhus typhina	3,5,9	—	—
Robinia pseudoacacia	1,3,5,6,7,8,9	—	—
Robinia pseudoacacia 'Umbraculifera'	3	—	—
Salix alba	—	2	1
Salix alba 'Tristis'	7	3	—
Salix matsudana 'Tortuosa'	3	—	—
Salix nigra	—	5	—
Salix species	1,7	—	—
Sorbus species	—	1,5	—
Syringa amurensis japonica	5	—	—
Tamarix pentandra	1,2,6,7,9	—	—
Taxus cuspidata	—	7	5
Thuja occidentalis	—	2	5

Tilia americana	—	5	7,8
Tilia cordata	—	—	2,7
Tilia euchlora	—	—	1
Tilia platyphyllos	1	—	—
Tsuga canadensis	—	—	5,7,8
Ulmus americana	—	5,7	8
Ulmus glabra	1,2	—	—
Ulmus pumila	7	5	—
Viburnum species	—	—	2

My work to date with *Ailanthus, Cercis, Coleus, Gleditsia, Hedera, Juniperus, Pinus, Pyracantha, Taxodium, Taxus,* and *Viburnum* has led me to believe that the degree of salt tolerance among herbaceous and woody plants depends on their ability to preclude Cl, and possibly Na, from entering cells. Chloride is preferentially accumulated over Na in most woody plant species regardless if the ions are soil- or aerial-applied. Sodium would, no doubt, prove as toxic as Cl if accumulated in similar levels.

Recent work (unpublished) comparing *Pinus thunbergii* Parl., Japanese black pine, a reported salt-tolerant species, to *Pinus strobus* L., eastern white pine, a salt-susceptible species, showed that both were injured by daily foliar applications of Cl salts. Tissue analyses revealed that needles of severely injured white pine had Cl contents greater than 4 percent, while injured needles (not to the degree of white pine) of Japanese black pine contained approximately 2 percent Cl. Anatomical investigations showed Japanese black pine needles have a cuticle-epidermal-subepidermal or hypodermal layer heavily impregnated with thickenings which is twice as thick as that of white pine. Resistance to Na and Cl entry is greater in Japanese black than white pine and this partially explains the lower Cl content in Japanese black pine needles. However, chloride did reach a threshold level in Japanese black pine which resulted in visual manifestation of injury.

Sodium and Cl accumulate in different amounts in various species (Table 2). The visual injury and degree of salt tolerance correlated closely with the shoot Cl levels. *Hedera* was more salt tolerant than *Viburnum>Pyracantha>Coleus>Cercis.* Chloride levels which induce toxicity symptoms in plants are difficult to compare because of the conditions under which the plants were grown and the tissues sampled. Tissue Na and Cl levels of injured plants vary because of (1) "species specificity" (genetic differences among plants), (2) plant part sampled (leaves usually possess greater concentrations of ions than stems, and stems greater levels than roots,), (3) time of sample collection [Hall, et al (11) showed that foliar concentrations of Na and Cl declined from abnormally high levels, up to 1 percent in May to normal levels, 0.02 to 0.1 percent, by August in white pine], and (4) analytical techniques. Lecroix, et al (18) showed that different analytical techniques indicated different Cl levels in the same tissue.

Figure 4. Eastern redcedar approximately thirty feet from the highways edge exhibiting dieback and one-sided habit.

Table 2. Chloride content of shoots of selected plant taxa.

Taxon	Cl, percent dry wt		
		NaCl	
	Control	0.05N	0.15N
Cercis canadensis	0.6	3.6	11.6
Coleus blumei	1.1	6.2	9.4
Hedera helix	0.4	1.4	1.9
Pyracantha coccinea 'Lalandi'	0.3	1.7	3.7
Viburnum x burkwoodii	0.3	0.9	2.2

There are many inherent problems in developing techniques for screening and selection of salt tolerant trees. The breeding work should

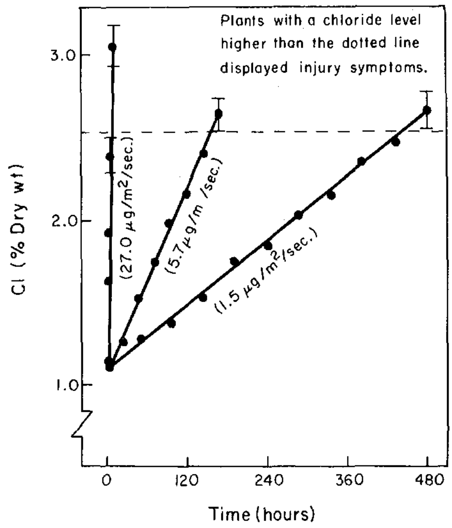

Figure 5. Chloride uptake of bean treated with three different rates of sea salt spray. Means compared between rates using Tukey statistic, 5% level (after Williams and Moser).

be concentrated within those families and genera which exhibit good salt tolerance rather than working with plant groups which display no tolerance. New cultivars which are finding their way into the market should also be screened. It will take time to make the appropriate crosses, grow the seedings, and to test and select promising individuals to be clonally propagated for highway and urban plantings.

Evaluations of salt-induced injury should be based on salts, concentrations, application methods (aerial- versus soil-applied), osmotic effects, shoot or leaf contents of Cl, and perhaps, shoot levels of Na. Elimination of any of these factors could result in misinterpretation of the salt resistance or susceptibility of a particular plant. Plant survival in saline soils does not automatically imply survival where salt is aerially applied and vice versa. *Thuja occidentalis* L., eastern arborvitae, will withstand soil salts but not foliar applied salts while the opposite is true for *Juglans nigra* L., black walnut. The appearance of the plant is not always indicative of the salt-induced damage (6) and dry weights of shoots or other growth parameters should be used to augment visual evaluations.

The plants listed in Table 1 have been evaluated for their salt tolerance by various authorities; however, they have not been systematically tested and therefore cannot be recommended unequivocally. There are obvious inconsistencies in the list and these occur because evaluations are based on a single parameter and insufficient data.

Salt damage to woody plants can be minimized or largely eliminated by:

1. Avoid deicing salts completely (often not feasible), reducing quantities applied, or using alternative deicing salts (17,30) or alternative methods of snow and ice removal.
2. If soil is inundated with salty water, or plants receive aerial drift, a thorough leaching of the soil or washing of the plant parts will aid in reducing injury—if done soon enough. Obviously such ameliorative treatments are impossible in large-scale situations (highways, malls, planters) but could be used to advantage by some homeowners. Another recommendation is the addition of gypsum to soils that are high in Na. The calcium displaces the Na and improves soil structure and aeration. Ayoub (1) reported a 30 to 85 percent reduction in leaf Na from plants grown in saline soils treated with gypsum. Anti-desiccants have also been recommended for alleviating salt injury. We have been unable to show any beneficial effect of anti-desiccants even when they were used at three times the recommended rate.
3. Snow fences, including living fences of shrubs, and certain changes in highway engineering could significantly reduce the problem of salt drift and salty runoff and provide other advantages as well (30). Mounding of planting areas would prevent accumulations of excess salt in the root zone. Flemer (9) advised that planting pits in sidewalks and blacktop areas should have a lip so the salty water does not run into the pits.

4. Plants that are injured and exhibit dieback should be pruned, fertilized, and watered. Weakened or stressed plants are often attacked by insects and diseases to which healthy trees are resistant.
5. Use plants sufficiently tolerant to the expected amounts and types of salt (soil salt or salt spray). As already mentioned, plants resistant to soil salts and those resistant to salt spray are not necessarily the same species. No plants are wholly immune to salt injury, although certain plant taxa endure more salt than others. A working list of woody plants, including those of good tolerance and moderate tolerance to the two types of salt, would significantly aid the landscape planner. Trees and shrubs with the highest degree of tolerance should be used in the most exposed areas, and those with moderate (and often increased ornamental characters) should be used in low-salt areas. The intolerant taxa would be restricted to areas where salts are not a problem.

Based on my work and that of other authorities I would rate *Elaeagnus angustifolia* L., *Gleditsia triacanthos inermis, Hippophae rhamnoides* L., *Pinus thunbergii,* and *Robinia pseudoacacia* L. as the most salt tolerant trees especially to aerial salts. As this meager list indicates we have much work to accomplish in the breeding-screening-selection of trees for salt tolerance.

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ABSTRACTS

Campana, R.J. 1976. **Air pollution effects on urban trees.** Trees Magazine 35(2): 35-38.

What are the principal air pollutants that are toxic to plants? What is their origin? How do they affect plants? How serious are they at present? What significance do they have for survival of the trees involved and what can be done to decrease or minimize damage from those of primary concern. The discussion here will include consideration of: the role of trees in the urban environment; the nature of air pollutants; comparative evaluation of damaging pollutants; comparative susceptibility of trees tested; the combined influence of air pollutants with other stress factors; compensatory aspects of air pollution; recommendations to reduce adverse impact from air pollution; and the significance of the problem for the future of urban tree management.

Mullin, R.E. and J.P. Parker. 1976. **Provisional guidelines for fall lifting for frozen overwinter storage of nursery stock.** Forestry Chronicle 52(1): 104.

Overwinter storage of nursery stock has many advantages to offer the nurseryman and tree planter. In recent years there has been (in northern climates) a shift from cold storage (above freezing temperatures) to frozen storage. However, frozen storage losses have occurred, and may be due to improper timing of the fall lift for storage. An experiment was started in the fall of 1972 to study the effects of the date of fall lifting on the post-planting performance of overwinter-stored white spruce and jack pine. Storage at two temperatures was used, 0 deg. F and 26 deg. F, with the former a failure, the latter successful. Spring planting indicated that "too early" outplanting is possible. Stored white spruce may be used to extend the planting season into late spring, but not jack pine.

Sterner, T.E., W.R. Newell, and F.A. Titus. 1976. **European elm bark beetle in New Brunswick—a new record.** Bi-Monthly Research Notes 32(3): 15.

Dutch elm disease was first found in the Maritime Provinces of Canada in 1957. The causal fungus, *Ceratocystis ulmi* has since spread, until in 1975 the disease is known to occur in 12 of 15 counties in New Brunswick and in 7 of 18 counties in Nova Scotia. The disease has not yet been found in Prince Edward Island. The chief vector of this disease is *Hylurgopinus rufipes* (Eichh.), the native elm bark beetle. *Scolytus multistriatus* (Marsh.), the European elm bark beetle, considered a primary vector in most of the United States, has not previously been trapped in the Maritimes Region. A single specimen of *S. multistriatus* was trapped at Upper Mills, Charlotte County, between June 23 and July 23, and is the first record of the European elm bark beetle trapped in the Maritime Provinces. Examination in October of about 50 elms within a 1-km radius of the trap did not reveal any galleries typical of *S. multistriatus,* indicating that the population of the European elm bark beetle is extremely low in the area surveyed.