PROSPECTS FOR SELECTING AND BREEDING TREES RESISTANT TO DEICING SALT [1]

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INTRODUCTION

The value of trees and woody shrubs to beautify city and residential streets and rural highways is generally accepted. Trees may also play significant roles in cleansing air and reducing temperatures, in addition to muffling noise, reducing wind speed, and providing shade and beauty. Excessive use of deicing salts creates a threat to the health and survival of trees along streets and highways.

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Population growth, urbanization, and availability of more leisure time have placed tremendous pressure on the use of our existing highway systems. The Transportation Association of America (1968) estimates that total intercity travel, measured in passenger miles, has tripled since 1945 and that automobile travel has more than quadrupled. This does not include the intracity and suburb-city commuting which has increased even more drastically.

Use of salt as a deicing chemical on U. S. highways has increased from one-half million tons to six million tons in the past 20 years, and is expected to level off at ten to twelve million tons per year (Westing 1969) or continue to increase because of more roads, increased traffic, and the demand by motorists for safer winter travel (Struzeski 1971).

There is abundant evidence on the damaging effects of deicing salts on the roadside plant biota in comprehensive literature reviews (Westing 1969; Hanes, Zelazny, and Blaser 1970; Struzeski 1971). The alteration of the roadside flora will include the decline and death of trees. Symptoms of injury in plants and trees include advanced coloration of foliage, leaf scorch, defoliation, stunting, and eventually die back. Available evidence indicates that deicing salt causes comparatively little lasting visible damage to roadside vegetation after the removal of dead foliage or dead plants. This does not preclude the possibility that there are less obvious effects on the vigor and competitive ability of individual species which may result in an alteration of the roadside flora (Davison 1971).

Many studies dealing with salt injury and death or roadside trees have focused on sugar maple decline which is occurring over a sixteen state area. Rich and Lacasse (1963) and Lacasse and Rich (1964) observed a rapid decline in maples and other trees along the highways of New Hampshire. They found a highly significant relationship between salt injury symptoms for tree distances and elevation within 30 feet of the highway. Maple decline was not found to be associated with age or any particular parasite or saprophytic fungi (Lacasse and Rich 1964).

The severity of the problem is easily recognized when you consider the number of trees each year that die from salt injury and are replaced along the thousands of miles of highways and streets receiving large quantities of salt. In 1957 the New Hampshire Highway Department reported 13,997 dead trees along 3,700 miles of highway. The cause of death of these trees was not specified, but many were thought to have died from salt injury (Rich 1972).

Resistant or tolerant trees planted initially would result in substantial savings in later years. The estimated cost of removal of the 13,997 dead trees along highways in New Hampshire in 1957 was one million dollars or an average of $70 per tree (Rich 1972). It is not unreasonable to expect costs to average S150 per tree for removal, purchase, and planting of another tree. Not all trees would be replaced along highways, but if half of them were, the cost would be around one million dollars for New Hampshire alone in 1957. Although no exact estimate is available, millions of dollars each year are spent replacing trees killed by deicing salts.

Salt Spray vs. Salt-Contaminated Soil:

Roadside plants may be injured by salt spray or salt-contaminated soil. Sauer (1967) believes that salt spray from highways may often be the major cause of roadside plant injury rather than salt being absorbed from the soil. Roadside injury to conifers has been reported up to 120 meters from highways by salt spray (Hofstra and Hall 1971). This distance is considerably more than the tree-free zone of six to fifteen meters from pavement that a few states have enacted for highway safety to vision and errant autos (Westing 1969).

Most salt in soil adjacent to highways in northeastern United States leaves the immediate area by surface runoff and leaching prior to the advent of the growing season (Holmes 1961). The effects of excessive concentrations of soluble salts on plant growth may be mediated by specific or nonspecific effects, or a combination of the two. Specific effects involve the specific ionic characteristic of the soil and are expressed as toxic effects or nutritional disturbances. Nonspecific effects, known as osmotic effects, are caused by the total salt concentration or activities, irrespective of type of salt (Bernstein and Hayward 1958). High osmotic pressure due to salts in saline soils generally causes moisture stresses within the plant; the consumption of water in a plant decreases as salt concentrations increase. Thus, one of the main effects of soil salinity is, perhaps, to limit the water consumption of plants, thereby inducing plant growth characteristics that typify water deficits (Hanes, Zelazny, and Blaser 1970).

In certain soil types, salt persists through the summer and fall with the accumulation of sodium and chloride over the years (Hutchinson and Olson 1967). The relatively abundant rainfall in the northern states in most cases overcomes this salt problem. Poor drainage patterns, lack of rainfall, and certain soil types can lead to extensive damage to vegetation from residual salt from winter applications.

Seasonal differences may be very important when evaluating the tolerance of conifers and hardwoods to salt spray or salt-contaminated soil. Conifers may be subjected to salt spray in the winter and salt-contaminated soil in spring and early summer. Hardwoods are subjected to only salt-contaminated soil since they shed their foliage in the fall. Conifers also have the disadvantage of retaining their foliage for more than one season and therefore they are subjected to additional accumulation periods of Ca, Na, and Cl ions.

Variation in Resistance or Tolerance:

Trees are generally much more sensitive to salt-contaminated soil than grasses (Davison 1971) although there is considerable variation in tolerance among species (Rudolfs 1919, Strong 1944, Zhemchuzhnikov 1946, Butijn 1954, van der Linde and van der Meiden 1954, Monk 1970, Monk and Wiebe 1961, Monk and Peterson 1962, Rich and Lacasse 1963, Bernstein 1964, Kotheimer et al. 1965, Zelazny 1968, Rich 1972) and within species (Rudolfs 1919, Holmes 1964, Shortle and Rich 1970).

Species differences in tolerance to soil-contaminated with salt may be due to genetic differences. The genetic differences in salt tolerance implied by differences among species can actually be quite subtle (Westing 1969). Baker (1965) has suggested genetic differences in trees in accumulating and transporting of sodium and chloride ions. Species with deep root systems may be tolerant to salt simply because the majority of their roots are below the soil layers with high concentrations of salt.

There may be different mechanisms for resistance or tolerance to salt spray and salt-contaminated soil. Holmes (1964) reported that analyses of leaves and twigs of salted oaks showed practically no increase in their chloride contents over the levels of check trees. However, he states, hurricane experiences indicate that oak foliage is sensitive to salt spray injury. Discounting the season of the year difference, there is no reason to assume the same mechanism is responsible for resistance in evergreens to salt spray and salt-contaminated soil.

Sources of Resistant Species, Varieties, and Clones:

Oceanside environments at the cooler latitudes should not be overlooked in the search for suitable genotypes (Westing 1969). Natural selections from hot, dry saline regions may not yield satisfactory results when the selections are grown in the cooler, wetter growing seasons of the northern areas. _Pinus radiata_ D. Don and _Pinus torreyana_ Parry grow close to the ocean and presumably these pines have resistance to salt spray. This also may be true of _Pinus thunbergii_ Parl. of Japan, _Pinus luchuensis_ Mayr of the Ryukyus and _Pinus massoniana_ Lamb. of China. _Pinus sylvestris_ L. comes very close to sea level along the coast of the Baltic Sea and _Pinus elliottii_ Engelm. grows along the coast of the Mississippi Sound and on offshore islands very close to the edge of the water (Mirov 1967). _Pinus nigra_ Arn. has been found to more resistant to salt spray than _Pinus sylvestris_ L. or _Pinus strobus_ L. (Wallace and Moss 1939).

Species, varieties, and clones recommended for highway and street plantings should be considered for investigation as to their tolerance to deicing salts. Many of these trees may have been selected for other characteristics, but some may also be tolerant to salts because of their success in harsh environments.

Table 1 gives the salt tolerance of trees and ornamentals taken from Zelazny (1968). The table gives plants arranged according to whether the plant is tolerant; moderately tolerant/sensitive; or sensitive. Within each class, the plants are listed in decreasing order of salt tolerance; however, differences of two or three places in the columns may not be significant. No explanation was given of the inconsistancy of hard maple being moderately tolerant and sugar maple being poorly tolerant. Table 2 gives salt tolerance of trees to salt spray. No attempt was made to combine findings across studies.

Table 1.--Tolerance of trees and ornamentals to salt-contaminated soil[a]

Tolerant	Moderately Tolerant	Poorly Tolerant
Common matrimony vine	Silver buffalo berry	Black walnut
Oleander	Arbor vitae	Little leaf linden
Bottlebrush	Spreading juniper	Barberry
Whate acacia	Lantana	Winged euonymus
English oak	Golden willow	Multiflora rose
Silver poplar	Ponderosa pine	Spiraea
Gray poplar	Green ash	Arctic blue willow
Black locust	Eastern red cedar	Viburnum
Honey locust	Japanese honeysuckle	Pineapple guava
Osier willow	Boxelder maple	Rose
White poplar	Siberian crab	European hornbeam
Scotch elm	European black currant	European beech
Russian olive	Pyracantha	Italian poplar
Squaw bush	Pittosporum	Black alder
Tamarix	Xylosma	Larch
Hawthorne	Texas privet	Sycamore maple
Red oak	Blue spruce	Speckled alder
White oak	Douglas fir	Lombardy poplar
Apricot	Balsam fir	Red maple
Mulberry	White spruce	Sugar maple
	Beech	Compact boxwood
	Hard maple	Filbert
	Cottonwood	
	Aspen	
	Birch	

[a] From Zelazny, L., 1968.

Table 2.--Tolerance of trees to salt spray

Hofstra and Hall (1971) (highway salt spray)	Wallace and Moss (1939) (hurricane)	Boyce (1954) (ocean salt spray)
Tolerant	Tolerant	
Austrian Pine	Austrian Pine	
Mugo Pine		
White Cedar		
Intermediate	Intermediate	Intermediate
Scotch Pine	Scotch Pine	Scotch Pine
Sensitive	Sensitive	Sensitive
E. White Pine	E. White Pine	E. White Pine
Red Pine		Loblolly Pine
		Longleaf Pine
		Pitch Pine

Questions That Need Answers:

Although a considerable amount of information is known about resistance of trees to deicing salts, the following questions need answers before a comprehensive improvement program can be undertaken to exploit genetic resistance of trees to deicing salts.

1. What are effective, low cost evaluation procedures to test trees tolerant to salt spray and salt-contaminated soil?

2. What traits or variables are adequate to measure salt tolerance of trees to deicing salt? Are these measures adequate for quantitative analyses?

3. Is there a correlation between tolerance or resistance to salt spray and salt-contaminated soil?

4. Is resistance or tolerance correlated between seedlings and mature trees?

5. How important are factors such as soil moisture, relative humidity, temperature, sunlight, soil type, salt concentration, and season of the year when evaluated according to the expression of tolerance or resistance?

6. How much variation in tolerance or resistance is there among and between species to salt spray and salt-contaminated soil?

7. How much genetic gain in tolerance or resistance can be realized using different selecting and breeding systems for different species?

8. What type and degree of genetic control of salt resistance operates in various species? How many genes control resistance and are they the same for salt spray and salt-contaminated soil?

9. Does soil salt resistance of grafted or budded plants reside in the stock, scion, or both?

Evaluation Procedures:

Conifers for highway plantings should be evaluated primarily for tolerance to salt spray. Deciduous species do not have to be evaluated since they are without foliage during the winter. Proper highway drainage design and good selection of planting sites should minimize the need for trees being tolerant to salt-contaminated soil due to salt laden surface water runoff along the major highways.

In rural and urban areas, however, trees planted close to highways and streets create the need for evaluating conifers tolerant to salt spray and salt-contaminated soil, and deciduous trees tolerant to salt-contaminated soil. These same trees will have to be tolerant to environmental stresses such as confined root systems, drought, narrow growing spaces, and air pollutants, to name a few.

Low cost procedures need to be developed and tested for evaluating tolerance of trees to salt spray and salt-contaminated soils. Procedures should include testing trees over a range of soil types, seasons of the year, temperatures, and salt concentrations. Holmes (1964) states that before the effect of salt can be predicted each tree species and each clone ought to be tested in soils of several different textures.

A few procedures have been used to evaluate tolerance of trees to salt-contaminated soil. Rudolfs (1919) applied NaC1 at rates ranging from one to ten pounds per individual tree. The study consisted of 66 oak, 23 birch, 24 maple, and 17 chestnut trees ranging from 8 to 18 feet in height. Injury was observed as early as six weeks after application, while serious injury and some dying occurred after ten weeks. The larger trees were more resistant than smaller ones of the same species.

Monk and Peterson (1962) tested the salt tolerance of twenty species of ornamental trees and shrubs using one-year-old seedlings. Treatments were applied with irrigation water and consisted of no salt, 4,000, 6,000, 8,000, and 10,000 ppm of total salt (mixture of equat part of NaC1 and $CaCl_2$). Some species showed little salt tolerance and did not survive the 4,000 ppm salt treatment. Other species survived 6,000 and 8,000 ppm salt treatments.

There are a number of variables to consider when evaluating the tolerance or resistance of seedlings or trees to salt-contaminated soil. A representative sample of the species, clone, or variety should be tested to make sure you are evaluating the parameter adequately. Trees should be tested using different soluble salt concentrations, soil types, and moisture conditions to see if there are genotype x environment interactions. The presence of interactions will determine what genotypes you recommend for different conditions. Seedlings could be tested in pots or more mature trees under actual field conditions. Testing is pots would allow for easier control over the treatments and treatment levels. It probably would be very expensive to evaluate a large number of species or varieties because of the number of plants per species needed, but relatively cheap for clones. Information is needed on how closely correlated juvenile and mature tolerance traits are in a number of species, Outplanting and field testing of the seedlings from the pots would furnish this information. It would be worthwhile to use the pot method on a few species of obtain good estimates of the variability in tolerance over a range of soluble salt concentrations, soil types, and moisture conditions.

No problems are anticipated in evaluating trees tolerant or resistant to salt spray. The concentration of salt in the testing solutions to simulate the concentrations reaching plant foliage may be very important. Environmental conditions and method of application should be evaluated adequately. Spraying or dipping foliage may be adequate application methods. The application method and environmental conditions should simulate salt spray from traffic as nearly as possible.

Salt spray from traffic occurs as a fine mist of water bubbles containing dissolved salts which drift with air currents and are deposited on roadside vegetation and soil (Struzeski 1971). This is analogous to the deposition of high concentrations of salt in the form of salt spray on coastal plants resulting in necrosis and death of leaves, twigs, and occasionally entire plants. Necrosis and death is due primarily to high accumulation of the chloride ion in the tissues (Boyce 1954). Boyce (1954) sprayed Iva plants with normal sea water once a day for two to three weeks in the summer. It remains to be seen whether injury mechanisms are the same during summer when Boyce (1954) did his studies and during the winter when salt spray injures conifers along streets and highways.

The variable to be measured in studying salt tolerance of trees may be somewhat of a problem, especially if a quantitative measure is desired. The degree of hypertrophy (Boyce 1951) and amount of necrosis exhibited by the foliage might be acceptable. Others could be the accumulation of Na, Ca, or Cl in the foliage. Monk and Wiebe (1961) measured salt hardiness using the plasmolytic and tetrazolium methods on 28 species of woody and herbaceous ornamental plants. They are rapid techniques but have the disadvantage of evaluating tissue as either dead or alive. There is good correlation between salt tolerance in field or solution cultures and both the plasmolytic and tetrazolium tests for salt hardiness (Monk and Wiebe 1961).

If evaluating procedures are developed and used to answer the necessary questions and furnish the necessary information, then selection and breeding systems can be implemented to improve trees resistant to deicing salts for urban and highway plantings. Some authors feel straightforward empirically screened selection and breeding programs for commercial seed production of resistant strains seem completely feasible (Strogonov 1962, Bernstein 1963, Epstein and Jefferies 1964, Westing 1969, Collins 1972).

What to Evaluate:

Of high priority is the evaluation of species, cultivars, and clones that are currently being planted in the highway and urban environments. The cost of testing them will be low compared to the cost of removing dead and dying trees and replanting.

New and better varieties can be developed through selection and breeding programs. It will take time to make appropriate crosses, grow out the seedlings produced, and to test and select promising individuals to be clonally propagated for highway and urban plantings.

To test the feasibility of breeding trees resistant to deicing salts, a few species should be selected and evaluated. Each species should be sampled over its range well enough to obtain good estimates of the species variability in tolerance or resistance. Conifers should be evaluated on salt spray tolerance and conifers and hardwoods for tolerance to salt-contaminated soil. The following species might be good ones to start with because they all can withstand some urban stresses and are in the following classes of tolerance to salt-contaminated soil or salt spray.

Tolerant	Moderately Tolerant	Poorly Tolerant
Honey locust	Green ash	Red maple
Hawthorne	Eastern red cedar	European hornbeam
Austrian pine	Scotch pine	Little leaf linden

SUMMARY

It should be possible to breed trees resistant or tolerant to deicing salt. There is abundant literature indicating considerable variation in tolerance among, and to a lesser extent within, species. Low cost procedures will have to be developed and tested to evaluate tolerance to salt spray and salt-contaminated soil. Straightforward selection and breeding programs could be used to develop resistant or tolerant clones or varieties for urban and highway plantings.

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