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# THE RESPONSE OF DORMANT NORWAY AND SUGAR MAPLES TO SIMULATED DE-ICING SALT SPRAY[1]

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**Abstract.** Norway maple and sugar maple trees sprayed during dormancy with salt solutions simulating salt spray along heavily salted roads in winter were less vigorous than those not exposed to salt. Fresh and dry weights of leaves, stems, and roots; height increase, and total shoot growth were greater in the unsalted trees. The percent of buds opened was also slightly greater on the unsalted plants. Percent dry weight was lower for the unsalted plants, indicating a higher water content than in the salted trees. Trees which were exposed to ambient conditions following the salt spray were generally in better condition than those protected from precipitation. Salt deposited on plant parts was probably washed away, preventing injury.

The influence of airborne salt on vegetation has been of concern since 1805 when Salisbury (20) in England associated leaf damage of coastal vegetation with onshore wind in the absence of rain. Beck (1) observed this phenomenon in the United States in 1819 at Salem, Massachusetts and New London, Connecticut, and Wells and Shunk (23) in 1937, attributed the peculiar misshapen appearance, or "molding" of plants along seacoasts to the salt carried by wind rather than to the wind per se.

In the 1950's salt effects again became of interest in the United States as a result of salt used for deicing roadways in snowbelt states (9). Rich (19) in 1968 observed the same range of sensitivity to tolerance among species as had been observed in the case of coastal vegetation. Others have contributed to the literature with descriptions of salt injury symptoms (4, 9, 13, 16), correlation between injury and salt content of plant tissues (10, 11, 14), and varying susceptibility of plants (6, 12, 22).

Basically, two types of problems arise from deicing salts: (1) salt which leaches through the soil into the root system and (2) salt spray on above-ground plant parts. Hofstra et al. (12) found little evidence of Na or Cl accumulation in soil beyond 30m from a highway. However, they found injury from salt spray and Na and Cl accumulation in plants as far as 120m from the road and thus consider salt spray the more damaging consequence of road deicing. A considerable amount of the salt deposited may be carried away within hours by the vehicles themselves or through brine spray or wind-borne crystals (11). This salt will impinge on the buds, stems, and bark of dormant deciduous trees and the needles of conifers. According to Blaser (3), Cl rather than Na is considered the toxic ion, Na being generally harmless to most plants.

The potential for direct needle injury or death may be the reason for the apparent greater susceptibility of conifers over deciduous species generally. Symptoms of salt damage in evergreens generally appear in late March or April when death of terminal buds and twig dieback may be observed (14). Damage to deciduous trees is apparent at the time of bud-break when injured buds fail to open (14). Flower buds appear to be even more sensitive than leaf buds (12).

Many roadside trees have been observed for injury and analyzed for Cl and/or Na content, but few controlled experiments document the se-

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quence of plant injury and decline following exposure to salt spray. Pykko (18) investigated salt spray effects on the growth and development of *P. sylvestris* along the shoreline of western Finland, but his study was confined to a single evergreen species exposed to salt spray throughout the year. Francis and Curtis (8) studied the vegetative effects of saline drift simulating cooling tower emissions. Although both evergreens and deciduous species were used, the salt exposures occurred only during the growing season when the deciduous trees were already in leaf and both groups were physiologically active.

In view of the fact that salt-spray from deicing salt occurs only during the winter when trees are dormant; and that conditions of light, temperature, and relative humidity during winter appear to be conducive to greater salt uptake by certain tree species (22), it would appear imperative to study salt spray effects on deciduous species during the dormant period.

The objective of this study, therefore, was to determine the effect of simulated salt spray on chloride uptake and subsequent growth of Norway maple (*Acer platanoides*) and sugar maple (*Acer saccharum*) exposed to salt spray during dormancy.

## Materials and Methods

Two-year-old bare-rooted Norway maples (seedling understock) and sugar maples (seed-grown) purchased from a nursery were transferred to sterilized soil-peat-sand mixture (1:1:1) in 3.8-liter containers at the beginning of September, 1981 and placed outdoors. During the winter of 1981-82, representative trees of each species were exposed in a sedimentation chamber to salt spray solution containing 40,000 ppm chloride as NaCl. Twenty-four trees of each species were exposed to salt spray on 13 days, 6 hr/per day, between December 1981 and March 1982. The frequency of spray treatments was based on a five-year average (1975-1980) of monthly snowfalls in New Brunswick, New Jersey which exceeded ½ in. (Table 1). Following each spray, twelve salted and twelve unsalted trees were placed outdoors, exposed to ambient conditions. An equal number were placed in an outdoor location that was protected from precipitation by a glass roof. The latter plants were watered with deionized water onto the soil.

The sedimentation chamber consisted of a 1-m-square by 1½-m-high wooden frame covered with polyethylene (24). A resealable flap allowed entrance into the chamber. Salt solution was forced up a 1-m-high, 10-cm-wide PVC column in the center of the chamber and exited through holes in the top. The spray then settled to the bottom of the chamber. Trees were placed on the floor of the chamber and exposed to the airborne salt. Salt deposition, determined by placing open petri plates at the bottom of the chamber and measuring the amount of salt collected on the plates, was expressed as micrograms of chloride per unit area (ugCl/cm$^2$).

Following the first winter, two trees per treatment were harvested, separated into buds, shoots, and roots, and weighed. Chloride analyses were performed on all tissues. Tree height and number of buds per tree were recorded for the remaining trees which were allowed to continue growth. On May 15, 1982, the number of buds which developed into leaves was recorded. Percent bud opening was calculated by dividing the total number of buds by the number which developed into leaves. Total plant height was measured and the change in height from the previous spring was calculated. Total shoot growth of each tree was determined by combining the lengths of the most recent internodes. The above procedure was repeated on the ten remaining trees of each treatment after the second winter.

**Table 1. Frequency of monthly snowfalls in New Brunswick, New Jersey[1] equal to or greater than 0.5 in. from 1975-1980.**

| *Month* | *1975* | *1976* | *1977* | *1978* | *1979* | *1980* | *Av.* |
|---|---|---|---|---|---|---|---|
| | | | | No. | | | |
| January | — | 4 | 7 | 7 | 5 | 2 | 5 |
| February | — | 3 | 2 | 5 | 3 | 1 | 3 |
| March | — | 1 | 1 | 2 | 0 | 4 | 2 |
| November | 0 | 0 | 1 | 1 | 0 | — | 1 |
| December | 3 | 2 | 0 | 0 | 3 | — | 2 |

[1]Data from U.S. Environmental Data and Information Service, National Climatic Center, Asheville, N.C.

*Chloride analysis of plant tissues.* All tissues were harvested, rinsed three times in distilled-deionized water and dried @ 75C for 48 hrs in a forced-air oven. The dried tissue was ground in a Wiley mill (Arthur Thomas, Philadelphia) through a 20-mesh screen. One hundred-mg samples were treated with boiling de-ionized water and allowed to soak for 1 hr. Suspensions were filtered through Whatman no. 4 filter paper, diluted to 50ml and analyzed for chloride using a Buchler Chloridometer (Cotlove, 1959). Chloride content was expressed as percent of dry wt.

## Results

### Norway maple

*Fresh and dry weights.* Total fresh and dry weights of the stems and leaves of the salted trees were significantly lower than the weights of the unsalted trees exposed to ambient conditions (Table 2). Tissue weights of trees protected from precipitation (covered), though lower in the salted trees, were not significantly different between salt treatments. Percent dry weight (fresh wt/dry wt) of tree foliage exposed to salt spray was significantly greater than that of the unsalted foliage (Table 2), but that of stems did not differ significantly between salt treatments.

*Growth.* Total height and percent bud opening did not differ significantly among salt treatments or environmental conditions. However, trees exposed to salt spray, whether grown openly or protected from precipitation, had significantly less shoot growth during the two-year period than the unsalted trees (Table 3).

*Chloride uptake.* Chloride content of the salted leaves protected from precipitation was significantly higher than in the unsalted leaves (Table 3). Foliage and stems from trees grown under ambient conditions showed no Cl differences between salt treatments.

### Sugar maple

*Fresh and dry weights.* Fresh and dry weights of leaves and stems of the covered and leaves of the uncovered sugar maples exposed to salt spray were significantly lower than the weights of tissues from trees not exposed to salt (Table 4), but the tissue weights of stems exposed to ambient conditions did not differ among salt treatments. Percent dry weight was greater in the salted leaves of both covered and uncovered trees, but not in the salted stems of the covered seedlings.

*Growth.* Total height and percent bud opening did not differ between salt treatments or between environmental conditions (Table 5). However, trees exposed to salt spray, whether grown in ambient conditions or covered, produced significantly less shoot growth during the 2-year period than the unsalted trees (Table 5).

*Chloride content.* Chloride content of salted, covered, or uncovered leaves or stems was not significantly higher than that of the unsalted leaves (Table 5).

**Table 2. Fresh and dry weights[1] and percent dry weight of stem and leaf tissues from salted and unsalted Norway maples grown under ambient conditions or protected from precipitation.**

| | Leaves | | | Stems | | |
|---|---|---|---|---|---|---|
| *Treatment* | *Fresh wt (g)* | *Dry wt (g)* | *% Dry wt* | *Fresh wt (g)* | *Dry wt (g)* | *% Dry wt* |
| **Ambient** | | | | | | |
| Unsalted | 33.2a | 15.2a | 45.8b | 69.2a | 43.8a | 63.3a |
| Salted | 20.6b | 10.2b | 54.5a | 56.6b | 38.5b | 68.1a |
| **Covered** | | | | | | |
| Unsalted | 13.0a | 7.3a | 49.6b | 50.4a | 31.5a | 62.5a |
| Salted | 9.1a | 5.1a | 61.8a | 46.2a | 30.2a | 68.2a |

[1]Each number is the mean of ten replicates. Numbers followed by the same letter in similar columns are not significantly different @ P = 0.05.

**Table 3. Percent bud opening, height increase, shoot length, and chloride content[1] of salted and unsalted Norway maple seedlings grown under ambient conditions or protected from precipitation.**

| | Buds opened (%) | | Height increase (cm) | Shoot length (cm) | Chloride content (% dwt) | |
|---|---|---|---|---|---|---|
| *Treatment* | *yr1* | *yr2* | *2yr total* | *2yr total* | *Leaves* | *Stems* |
| **Ambient** | | | | | | |
| Unsalted | 55a | 32a | 33.4a | 166.6a | 0.19a | 0.11a |
| Salted | 47a | 32a | 34.5a | 112.1b | 0.25a | 0.16a |
| **Covered** | | | | | | |
| Unsalted | 45a | 36a | 40.2a | 147.4a | 1.01a | 0.27a |
| Salted | 41a | 30a | 47.4a | 101.7b | 1.80b | 0.33a |

[1]Each number is the mean of ten replicates. Numbers in the same column followed by the same letter are not significantly different @ P = 0.05.

## Discussion

Total plant height and percent bud emergence in the spring were not affected by salt spray in either species in the present study. Hofstra et al. (12) observed the death of shoot tips of deciduous trees growing adjacent to a heavily salted highway in Ontario, Canada. The buds did not emerge in the spring following many salt applications. Lumis et al. (14) observed the same symptoms on beech and dogwood. Buds facing the road also failed to open in the spring. Affected branches had new growth at the base but buds further out on the branches were aborted. Injured plants thus had a tufted appearance on the side of the tree facing away from the road. Chloride dosages used in the present study apparently were not high enough to cause bud inhibition or visible injury. However, shoot growth was significantly reduced by the dormant salt spray. Pyyko (18) also found reduced shoot growth in Scots pine exposed to sea salt, but no effect on bud opening. Bean plants exposed to high soil salinity by Meiri et al. (15) also exhibited growth reduction without visual symptoms. Transfer of the bean plants from a saline to a non-saline medium resulted in a "transient" burst of growth and an increased transpiration rate, but not to the level of non-salinized control plants.

Lower tissue weights of the salted plants in the present study also indicated poor growth due to Cl and Na uptake from the salt spray. Others have reported decreased biomass in various species grown in saline soils. Percent dry weights in the tissues of plantago plants subjected to substrate-salt by Erdei and Kuiper (7) and of the maples exposed to airborne salt in the present study were both higher than in untreated controls, indicating reduced moisture content. Erdei and Kuiper (7) attributed the increased dry weight in plantago to a high internal ion content. Petolino (17), on the other hand, found an increase in the absolute water content of the leaves of beans exposed to saline spray expressed either on an area or a weight basis, but no change in the relative water content (an estimation of the relative turgidity of the tissues). He suggested that the tissues might have had to absorb more water to dilute the excess salt and maintain the same water potential. Bernstein and Hayward (2) reported that even though transpiration and water uptake increased in salt-stressed plants, growth was still reduced. In the present study growth reduction and decreased hydration of the tissues went hand in hand.

Covering the salt-treated trees caused reduced growth in both leaves and stems of Norway maple but only in the leaves of sugar maple. Chloride content of leaves and stems was much less in the seedlings exposed to ambient conditions. That this occurred also in supposedly unsalted seedlings appears most irregular. Leaching of soil salt might have been responsible. Hofstra et al. (12)

**Table 4. Fresh and dry weights and percent dry weight[1] of stem and leaf tissues from salted and unsalted sugar maples grown under ambient conditions or protected from precipitation.**

| Treatment | Leaves: Fresh wt (g) | Leaves: Dry wt (g) | Leaves: % Dry wt | Stems: Fresh wt (g) | Stems: Dry wt (g) | Stems: % Dry wt |
|---|---|---|---|---|---|---|
| **Ambient** | | | | | | |
| Unsalted | 22.1a | 10.3a | 49.3b | 22.8a | 13.3a | 58.8b |
| Salted | 18.2b | 6.8b | 63.7a | 21.5a | 7.0a | 68.5a |
| **Covered** | | | | | | |
| Unsalted | 13.0a | 6.7a | 49.6b | 50.3a | 31.0a | 60.7a |
| Salted | 5.7b | 3.4b | 78.8a | 16.1b | 8.7b | 64.3a |

[1]Each number is the mean of ten replicates. Numbers followed by the same letter in similar columns are not significantly different @ P = 0.05.

**Table 5. Percent bud opening, height increase, shoot length, and chloride content[1] of salted and unsalted sugar maple seedlings grown under ambient conditions or protected from precipitation.**

| Treatment | Buds opened (%): Yr1 | Buds opened (%): Yr2 | Height increase (cm): 2Yr total | Shoot length (cm): 2Yr total | Chloride content (% dwt): Leaves | Chloride content (% dwt): Stems |
|---|---|---|---|---|---|---|
| **Ambient** | | | | | | |
| Unsalted | 28a | 35a | 29.2a | 72.3a | 0.29b | 0.15b |
| Salted | 30a | 34a | 24.6a | 59.6b | 0.29b | 0.16b |
| **Covered** | | | | | | |
| Unsalted | 28a | 37a | 16.3b | 67.7a | 1.37a | 0.34a |
| Salted | 30a | 35a | 18.3a | 58.9b | 1.51a | 0.64a |

[1]Each number is the mean of ten replicates. Numbers in the same column followed by the same letter are not significantly different @ P = 0.05.

reported the leaching of Cl from leaves of white pines sprayed with saline solution by subsequent rain. DeTemmerman et al. (5) also observed leaching of Cl by rain from pines exposed to saline spray and emphasized the greater hazard to conifers posed by a dry spring than by a rainy season following a winter when salt has been used for deicing roads.

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