The Damage of Deicing Salt on Two Spruce Tree Species Planted along Roadsides in Northern Japan


* Hokkaido Research Center, Forest and Forest Products Research Institute, Sapporo 062-8516, Japan
** Symbiotech Research Inc., Alberta T9E 7N5, Canada.
*** Hokkaido University Forests, FSC, Sapporo 060-0809, Japan.

Abstract

The growth of two spruce species (Picea abies (L.) Karst., and Picea glehnii Masters) planted along roadsides is often reduced by salt stresses. To analyze the toxicity of deicing salts, we measured needle lifespan, and the concentration of chlorophyll, sodium, and chlorine of the two spruce species at damaged and healthy sites. In the needles of P. abies large amounts of sodium and chlorine were detected, especially in winter. Chlorophyll concentration in needles of P. abies decreased, and needle shedding accelerated. By contrast, in P. glehnii no difference was found in the concentration of sodium, chlorine, and chlorophyll, and in survivorship of needles between summer and winter. Therefore, we concluded that effect of salt spray was larger for the site of P. abies than that of P. glehnii.

Key words: Chlorophyll, Deicing salt, Needle injury, Needle life span, Spruce,

1. Introduction

Conifers along roadsides have been declining in various countries in cold regions, and deicing salt seems to be a possible cause of this decline (Larcher, 1995). On conifers adversely affected by deicing salt, needle color changed to brown, and needle shedding was accelerated (e.g. Hautala et al., 1992; Viskari and Kärenlampi, 2000). Spruce species are known to have a higher sensitivity to salt than other woody species (Larcher, 1995).

In previous research conducted at a damaged site, large amounts of sodium (Na) and chlorine (Cl) were detected in the soil and snow (Kayama et al., 2003). These elements accumulated in the needles of spruce at this site. Needle lifespan, mycorrhizal infection and physiological function decreased in spruce planted at this damaged site. Moreover, Picea abies shedded its needles faster than Picea glehnii. It therefore seems that P. abies may have higher sensitivity to deicing salts than P. glehnii. However, when do deicing salts affect on decline of spruce?

The objective of this study is to examine the direct effects of salt spray in winter for two declining spruce species planted along highways. The physiological traits examined are: 1) needle lifespan as an indicator of the needle shedding of spruce, 2) concentration of chlorophyll as an indicator of needle colour, and 3) trace elements in needles. These parameters were compared with summer, when direct effects of salt spray were little.

2. Materials and Methods

2.1 Study site

The study sites were located along a highway in northern Japan (43°07' N, 141°46' E, 60 m a.s.l.). The mean annual precipitation is 1,200 mm yr⁻¹, and the mean snow depth in the middle of the winter is 107 cm (Kayama et al., 2003). Deicing salt has been sprinkled over the highway during the winter for over 15 years. Snow on the highway was regularly cleared by snowplows, which involved plowing it to the side of the road. The main component of deicing salt is sodium chloride. (Japan Highway Public Corporation, unpublished data). The concentrations of sodium and chlorine in snow of damaged site were 28.3 mg l⁻¹ and 59.3 mg l⁻¹ for P. abies, and 13.5 mg l⁻¹ and 23.8 mg l⁻¹ for P. glehnii (February 2002; Kayama et al., 2003). We selected two damaged sites (10 m × 50 m), i.e. the damaged site had either P. abies or P. glehnii. The density of each plantation was 5,000 trees ha⁻¹.

2.2 Measurement of needle survival

In July 2001 and early March 2002, four branches from three individuals of the two spruces from the damaged sites were sampled to estimate needle survival. The branches at sun crown were selected from the forest edge. Three shoots of each age of the two spruces were dried for 4 days at 80°C. After drying, survival of the needles was calculated from the ratio of the actual number of needles to the sum of the total number of needle scars and the actual number of needles (Kayama et al., 2002).

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2.3 Analysis of chlorophyll and elements in needles

Four branches of two spruces at the damaged sites were sampled. Samples were divided into needle age groups. Every age of needle was selected for analysis. Chlorophyll was extracted with dimethyl sulphoxide (DMSO) and measured by a spectrophotometer (Type 100-50, Hitachi Co., Tokyo, Japan). The remainders of the needles were dried at 80°C for 4 days. Dried samples were then ground to a fine powder using a vibrating sample mill (TI-100; Tester Industry Co., Tokyo, Japan), and digested by a microwave digestion system (O-I Analytical, College Station, TX, USA). Na concentrations were analyzed using an ICP analyzer (IRIS, Jarrel ash, Franklin, MA, USA), and Cl was analyzed by titration using the Mohr method.

2.4 Statistical analysis

The mean values for survivorship of needles and concentrations of chlorophyll and elements were determined by a t-test using Stat View 5.0 (SAS Institute Inc.). From these figures, the mean values of P. abies and P. glehni were compared between summer and winter. The symbols *, **, and *** indicate a statistical significance of 5, 1 and 0.1%, respectively.

3. Results and Discussion

3.1 Survival of needles

Survival of each age of needles decreased for P. abies in winter (P<0.01, Fig. 1). By contrast, needle survival of P. glehni showed no difference between summer and winter. Comparing the two spruce, needle survivorship for P. abies decreased by needle aging, and this decrease was more sharp than that for P. glehni.

3.2 Concentrations of chlorophyll and elements

Needle chlorophyll (a+b) of P. abies decreased in winter for each age of needle (P<0.05, Fig. 2). In particular, the needle color of P. abies changed to brown in winter, whilst P. glehni did not. Na concentration of P. abies increased with needle aging in summer (Fig. 3). In winter, Na for P. abies increased drastically for every age of needles (P<0.05). Also, Na in the needles of P. glehni increased with needle aging until three years, although its concentration did not increase in winter.

3.3 Discussion

Based on our results, high Na and Cl were detected in needles of P. abies in winter (Fig. 3). Na and Cl in needles of P. abies in winter were high for every age of needle. This result suggests that salt probably sprayed all around the needles of P. abies. As a result, the concentration of chlorophyll decreased because of browning of the needles (Fig. 2). Consequently, needle shedding of P. abies was accelerated (Fig. 1). By contrast, Na and Cl did not increase for P. glehni in winter. Therefore, the direct effect on needles of P. glehni was little compared with P. abies. However, the physiological function of P. glehni decreased in the growing season (Kayama et al., 2003). It seems that P. glehni only suffered indirectly from the effects of deicing salt. The difference of the direct effect of deicing salts may be the difference of traffic. Traffic at the P. abies site was one and a half times larger than that of P. glehni (unpublished data). The amount of deicing salt used may also have been different.

Na and Cl concentrations in needles of P. abies in winter were 6.9, and 7.1 mg g⁻¹ DM. This value is higher than other studies (e.g. Hauata et al., 1992; Viskari and Kärenlampi, 2000). Therefore, the amount of deicing salt used may also be higher than other regions. In addition, this highway was built by banks, and the road surface is relatively high. As a result, this highway experiences high winds in winter that might blow deicing salt to the roadside. To eliminate harmful effect of deicing salt at P. abies site, we should decrease the amount of salt used, or change the composition from NaCl to a less toxic chemical (Larcher, 1995). Furthermore, we should protect plantation area against deicing salt by fencing along the roads.

![Fig. 1. Survivorship of needles at different ages for P. abies and P. glehni in different seasons planted at damaged site (Mean ± SD, n=12). ** P<0.01 and *** P<0.001](image-url)
Fig. 2. Concentration of chlorophyll (a+b) in needles at different ages for P. abies and P. glehnii in different seasons planted at damaged site (Mean ± SD, n=4). *P<0.05, **P<0.01 and *** P<0.001

Fig. 3. Concentrations of Na and Cl in needles at different ages for P. abies and P. glehnii in different seasons planted at damaged site (Mean ± SD, n=4). *P<0.05 and ** P<0.01

References