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Road Salt Germination Inhibition of Native Plants Used in Roadside Plantings

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ABSTRACT

Many Midwestern states are using native roadside plantings to decrease maintenance requirements and increase visual appeal. These plantings receive salt from the highways from spray, blowing, or plowing. This study investigated the possible effects of several salt concentrations on seven species of plants native to Illinois: butterfly milkweed (*Asclepias tuberosa*), pale purple coneflower (*Echinacea pallida*), rattlesnake master (*Eryngium yuccifolium*), rough blazing star (*Liatris aspera*), Ohio spiderwort (*Tradescantia ohiensis*), little bluestem (*Schizachyrium scoparium*), and prairie dropseed (*Sporobolus heterolepis*). Soil samples were collected from the roadsides to determine amount of salt present. Field plots were established and salted at several levels which included typical highway application rates (0 kg/m^2, 1kg/ m^2, 2kg/m^2, and 3kg/m^2). Seeds were sown in field plots to test for germination. Seeds also were germinated under laboratory conditions using saline concentrations of 0, 0.25, 0.5, 1.0, and 2.0 g/L (last four solutions equal to approximately 0.009 M, 0.018 M, 0.035 M and 0.070 M solutions). Higher levels of salinity inhibited germination, but these levels generally were not found in the soil samples. All species tested showed tolerance of concentrations found in roadside samples.

INTRODUCTION

Illinois and other Midwest states have ongoing programs of planting native forbs and grasses along major highways. Midwestern native plants, highly adapted to the Illinois environment, are intended to increase the visual appeal of the roadsides and to decrease the amount of mowing required (Harrington, 1991). However, human actions have added factors unnatural to the native species. The use of salt for winter deicing is altering the roadside environment. Salt spray is known to inhibit growth, and in some cases, to kill roadside vegetation (Davison, 1971; Hughes et al., 1975; Sucoff, 1975; Morton Arboretum). In the winter of 2000-2001, the Illinois Department of Transportation (IDOT) used 590,000 tons of salt or 535,239 metric tons on 42,600 lane-miles of highway (a lane-mile is an area of pavement one lane wide and one mile long; Clough, pers. comm., 2001). This amount corresponds to about five lbs. /road ft or 2.3 kg/road ft. A road-foot is one lane wide and a length of 1 foot.

Much of the research on the effects of salt has been done on halophytes, salt tolerant plants. Katembe et al. (1998) tested whether salt had a toxic effect on seeds, or if changes in seed germination were a result of osmotic influence. Several studies on halophytes showed that salinity affects imbibition of water by seeds, and that some salt treated seeds would germinate after being washed with distilled water (Macke and Ungar, 1971; Redmann, 1972; Keiffer and Ungar, 1997; Bajji et al., 2002).

Everitt et al. (1983) studied the introduced and naturalized plant *Kochia scoparia*, commonly found on roadsides and waste areas. Germination was not affected at conductance up to 20 mmhos or 20 decisiemens/m (dS/m; Pearcy et al., 1991). A study of five grass species found that forage yield or biomass production was reduced at higher salt levels, and emergence was delayed (Hughes et al., 1975). The salinity tolerance of turf grasses such as Kentucky bluegrass (*Poa pratensis* L.) has also been studied in the greenhouse and in the field to determine the effect on forage yield (Woods, 1996).

The impact on native plants is less well documented than for forage or crop plants. Fulbright (1988) studied salinity impact on varieties of Indian grass (*Sorghastrum nutans* L.), a native warm-season grass used for range seeding. The study was to determine the effects of salinity and other factors on germination of Indian grass varieties. Percent germination was reduced in all varieties. Harrington and Meikle (1992) measured road salt effects on prairie species used in Wisconsin roadside plantings. In greenhouse testing using NaCl, all species showed reduced germination and growth at concentrations of 5 g/L or higher. Results of a study conducted on early goldenrod (*Solidago juncea*) and slender wheatgrass (*Agropyron trachycaulum*) suggested that roadside populations of the two species evolved higher salt tolerance than non-roadside populations (Pitelka and Kellogg 1979).

Although the use of native plants could reduce the cost of maintaining rights-of-way, increase habitat for native fauna, and increase the scenic beauty of our roadways, native seeds can be expensive. Salt-tolerant nonnative road mix seed costs from $580/ha to $667/ha, whereas native forb seed costs from $1,670/ha to $6,920/ha (Conserv FS, 2007; Tri County Stockdale Company of Joliet, 2007). The seed mix should be formulated for diversity and the ability to survive the sometimes harsh roadside conditions. By analyzing the ability of species to survive exposure to a seasonally saline environment, seed mixes can be developed for the greatest chance of success. This study measured the germination of native species under a range of saline conditions in the laboratory and compared these results to seedling establishment in field plots. Two predictions were tested: 1) that salt solution concentrations resulting from typical rates of road salt application would inhibit seed germination and seedling establishment, and 2) that seed germination responses in the field among study species would be similar to germination responses in the laboratory at similar salt solution concentrations.

METHODS

Soil Salinity

Soil samples were collected from the margin of Illinois Rt. 50, a north-south four-lane road, on April 3 and 7, 2001. Samples were collected from two stretches of road, Bradley to Manteno (6 km) and Manteno to Peotone (7 km) in northeast Kankakee County and southeast Will County. Both sections of road have remnant prairie on the west side between the road and the parallel Illinois Central Railroad tracks. Samples were collected every 0.8 km on alternating sides of the road. Samples were collected at the edge of the gravel parking strip, the bottom of the drainage ditch, and the outer edge of the drainage ditch and sealed into plastic bags. Distances from the edge of the pavement varied from 3-5 meters due to variations in the roadside structure. Soil samples were collected using a 7.6 cm diameter soil auger, to a depth of 8 cm. All soils collected were silt loams or silty clay loams. Samples comprised Andres, Beecher, Elliott, Symerton and Varna silt loams; and Ashcum, Elliott and Pella silty clay loams (Hanson, 2004; Deniger, 2005).

Soil samples were weighed, dried for 24 hrs, and reweighed to determine water content. A 10 g dry weight subsample of each soil sample was mixed with 100 ml of distilled water, and salt concentration of the solution was determined using a YSI Model 33 S-C-T conductivity meter (Yellow Spring Instrument Co., Yellow Springs, Colorado). A calibration curve, generated using known concentrations, was then used to determine salt concentrations of soil samples.

Soil samples also were collected, using the same methods as described above, from field plots on the campus of Governors State University at the conclusion of this study in July 2002, to compare the salinity levels in the field study, the roadside samples, and treatments used in the lab.

Species selection

The species used in both the laboratory and field portions of this study were butterfly milkweed (*Asclepias tuberosa* L.: Asclepiadaceae), pale purple coneflower (*Echinacea pallida* Nutt.: Asteraceae), rattlesnake master (*Eryngium yuccifolium* Michx.: Apiaceae), rough blazing star (*Liatris aspera* Michx.: Asteraceae), Ohio spiderwort (*Tradescantia ohiensis* Raf.: Commelinaceae), little bluestem (*Schizachyrium scoparium* Michx.: Poaceae), and prairie dropseed (*Sporobolus heterolepis* L.: Poaceae). These species, commonly used in roadside plantings, are generally found in mesic to xeric environments. Species that customarily have bacterial inoculation were not included in this study because the salt might have influenced the bacteria and not the seeds.

Laboratory study

Because seeds of the study species require cold stratification for germination, during April 2002 seeds were dark stratified in a Percival Scientific Model RE-9BH environmental chamber at 3º C for 30 days. Seeds then were placed in petri dishes with filter paper wetted with the appropriate salt solution so that the filter paper was saturated, but the seeds were not in standing water. Five dishes with 20 seeds per dish were used at each of five salinity levels. The five salt solutions were distilled water for the control and 0.25 g/L, 0.5 g/L, 1.0 g/L, and 2.0 g/L solutions of road salt in distilled water. These salinity levels were determined from the soil samples and other research (Redmann, 1972; Hughes et al., 1975; Everitt et al., 1983; Fulbright, 1988; Harrington and Meikle, 1992).

Road salt obtained from Governors State University (Cargill bulk ice control salt, Avery Island, LA) was used in the salt solutions to keep conditions as realistic as possible. The road salt contained 99% and 1% osmotic equivalents of NaCl and $CaCl_2$, respectively.

Consequently, the 0.25 g/L, 0.5 g/L, 1.0 g/L and 2.0 g/L salt solutions were equivalent to approximately 0.009 M, 0.018 M, 0.035 M and 0.070 M solutions.

After seeds were placed in petri dishes, 3 ml of salt solution was added to each dish and the dishes were sealed using Parafilm®. Because the relationship between conductivity and solute water potential varies with the specific ions present (Pearcy et al., 1991), a standard curve was constructed to determine the relationship between salt concentration (g/L) and conductance (umhos).

Petri dishes were maintained at a 12hr/12hr light/dark cycle at 25° C/15° C for six weeks and 25° C/20° C for two more weeks. Dishes were checked weekly and distilled water added as needed to maintain the salt concentration levels. Germinants were counted and removed to prevent any possible allelopathic impact. Seeds were considered germinated when the radicle was longer than 3 mm.

Field study

A field study area was established in old field vegetation on the campus of Governors State University. The area selected was away from the main campus and any major roadways or parking lots that might be salted. The soil type was a Frankfort silty-clay loam. A randomized block design with five blocks was used; each block contained four 1 m^2 plots. Each block included all treatments. Blocks were chosen on level ground to avoid drainage from one treatment to another. Treatments were randomly assigned to plots within each block.

The plots were mowed, treated with the herbicide Round-up®, and surface tilled in August 2001. The area within 0.5 m of the edges was trimmed to minimize competition from outside the study area. Seeds were planted in September 2001 to allow for natural stratification over the winter. Seeds were planted 2-3 cm apart in two rows within each plot with 50 seeds/species/row. Rows were 6 cm apart. Road salt identical to that used in the laboratory study was surface applied without removing snow, after snow falls measuring at least 5 cm. The winter was unusually mild and no major snow occurred until January 21, 2002. Road salt application dates were January 21, February 2 and 4 and March 4 and 25, 2002. The four cumulative salt treatment rates in this study were 0, 1, 2, and 3 kg/m^2 over the five application dates. The rate of application used by IDOT is estimated at 5-lbs/road ft or 2.4 kg/m^2 (Clough, pers. comm.., 2001), based on one road foot being approximately 10 ft^2. Plots were checked weekly during May and June 2002, and the seedlings were identified and counted. Plots were fenced in the spring when it was noticed that deer had been scraping at the ground, especially in the 3 kg/m^2 treatment plots. Total germination per treatment was compared using a Kruskal-Wallis test for tied ranks and nonparametric Nemenyi tests (Zar, 1999).

RESULTS

Soil salinity

Salinity of soil samples varied with distance from the road (Table 1), with salinities of samples taken from the parking strip slightly higher and soil samples taken farthest from the road with the lowest salinity levels. Salinities increased slightly from Manteno to

Peotone; this trend may reflect different application rates between Kankakee and Will counties.

Soil samples collected from the field study area for comparison had the expected variation between treatment levels (Table 2). The values measured on the roadside fell into the range of concentrations found in the field study. The highest application rate, 3 kg/m^2, was at the high range of the concentrations found in the road samples.

Laboratory study

Germination for most species varied from 28% to 88% with the exception of spiderwort, that had less than 1% germination (Fig. 1e) and rattlesnake master that did not germinate in the first trial. A second set of petri dishes was prepared using rattlesnake master from a different seed source, resulting in better germination. Results for rattlesnake master ($0.10<p<0.25$: hereafter results of Kruskal-Wallis test unless otherwise noted) and butterfly milkweed ($p>0.995$) showed no germination difference at any levels of salinity. Pale purple coneflower ($0.05<p<0.1$) showed a slight decrease in germination at the highest levels of application (Fig. 1b). Blazing star had the only major difference ($0.025<p<0.05$), with lowest germination rates occurring at the highest concentration of 2 g/L (Fig. 1a). Little bluestem showed little overall variation ($0.25<p<0.5$) but a slight increase in germination at the 2.0g/L concentration (Fig. 1c). Prairie dropseed seemed to have a slight increase in germination at 0.5g/L (Fig 1d) but the overall change was not significant ($0.05<p<0.1$).

Field study

Three species, spiderwort ($p<0.01$), butterfly milkweed ($p<0.001$), and pale purple coneflower ($p<0.005$) had germination differences due to salinity. Spiderwort (Fig. 2e) germination was most affected at 2 kg/m2. Butterfly milkweed (Fig. 2g) showed a decline even with the lowest application rate of 1kg/m2 (Nemenyi test $p=0.05$). Blazing star germination (Fig. 2a) also declined rapidly even at the lowest application rate with 8.5% germination in the control plots, 1.5% germination at 1 kg/m2, and no germinants at the higher levels. Pale purple coneflower (Fig. 2b) had the highest control germination rate at 96%. Germination declined significantly at 2 kg/m2, but this species still had the highest germination rate of all species at that salinity.

Rattlesnake master (Fig. 2f) had low germination and did not show an overall statistical difference ($0.25<p<0.5$). However, rattlesnake master appeared to have an increase in germination at the medium salinity levels, with the highest germination rates occurring at 2 kg/m2, and a decline in germination rate at 3 kg/m2 application rate.

The grasses, little bluestem (Fig. 3c) and prairie dropseed (Fig. 3d), had low germination levels even in the control plots; consequently the data were not statistically analyzed.

DISCUSSION

The results of this experiment indicate that saline concentrations typical of roadside application can inhibit germination of the tested native species. However, the levels needed to inhibit germination may not be present where native species are growing. The highest concentrations of salt in this study were in the areas closest to the road, 3-5 meters from the edge of the road. These areas are often mowed and/or sprayed to control growth of all plants. Areas planted with native species are farther from the road, often at distances of 10-20 meters. Soil samples collected farthest from the road in this study had salinity levels at or below the levels that caused a significant decrease in germination in the lab (2g/L) and in the field (1 kg/m^2).

The species with highest germination rates even at high salt concentrations in the field were pale purple coneflower, spiderwort, and butterfly milkweed. Pale purple coneflower had the highest germination levels at all salt application levels. Because these three species also have high visual appeal and are prolific seeders, use of these species along roadsides seems appropriate. It would be interesting to determine if these levels would have the same effect on mesic and wet prairie species. Unexpectedly, plant species showed less seed germination inhibition in the laboratory study than in the field study, most likely because the highest salt concentration used in the laboratory study (2 g/L) was equivalent to only the mid range of the salt application rates used in the field study (Table 2). Because germination occurred primarily during the spring months, but soil samples were not collected from field plots for salt concentration determinations until July, soil salt concentrations during seed germination may well have been even higher than measured from the soil samples.

It is challenging to compare this study to other studies, as different units and methods for measuring the amount of salt in the samples were frequently used. Harrington and Meikle (1992), measuring salinity in ppm in six-inch plastic pots, found significant declines in seed germination at 300-400 ppm, similar to 0.25 to 0.50 g/L used in this study. Fulbright (1988), using molarity, found a significant decline at 0.12 M, approximately equal to 3.4 g/L in this study. This concentration is higher than all of the concentrations used in our laboratory experiment, and is near the high extreme for soil samples collected from the roadside or from our field experiment. Harrington and Meikle (1992) and Ungar (1974) also noted that salinity could delay germination. This result may become a factor if the delay decreases the competitiveness of the native species to introduced cool-season grasses. Saline conditions may also affect the ability of mycorrhizal fungi and symbiotic bacteria in legumes to survive.

Overall, road salt application appeared to have a minimal impact on the establishment of native prairie species in this study. It was surprising, however, to find such high levels of salt remaining in the field plots at the end of the experiment. If salt can persist in the soils, this may allow for a long term, cumulative effect on seed germination and plant survival. Other factors, however, such as invasive alien species, are probably a bigger threat to establishment and survival of Midwestern native plant species. Although salt application can have detrimental effects on some native species and natural ecosystems (Environment Canada, 2001; Kaushal et al. 2005), results from this study suggest that application of salt along Midwestern roadsides is not a major impediment to establishment of plant species native to mesic to dry tallgrass prairie.

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Table 1. Soil salt concentrations (g/L) from samples collected every 0.8 km along 13 km of Illinois Rt.50 in Will and Kankakee Counties, March 2001.

Location of soil sample collection	Bradley-Manteno (6 km) (mean ± S.E., n = 8)	Manteno-Peotone (7 km) (mean ± S.E., n = 10)
Parking Strip	2.53 ± 1.20	4.58 ± 2.87
Roadside Ditch	2.26 ± 1.51	3.16 ± 1.79
Outside Ditch	1.64 ± 1.27	2.43 ± 2.03

Table 2. Soil salt concentrations (g/L) from field plots, Governors State University campus, July 2002. Road salt was applied from January to March 2002.

Road salt application rate	Soil salt concentration (mean ± S.E., n = 5)
0 kg/m^2	0.15 ± 0.10
1 kg/m^2	1.38 ± 0.70
2 kg/m^2	2.21 ± 1.15
3 kg/m^2	4.04 ± 2.05

Fig. 1. Percent germination (median ± range) of seven prairie species in petri dishes with road salt concentrations of 0, 0.25, 0.5, 1.0, and 2.0 g/L of water.

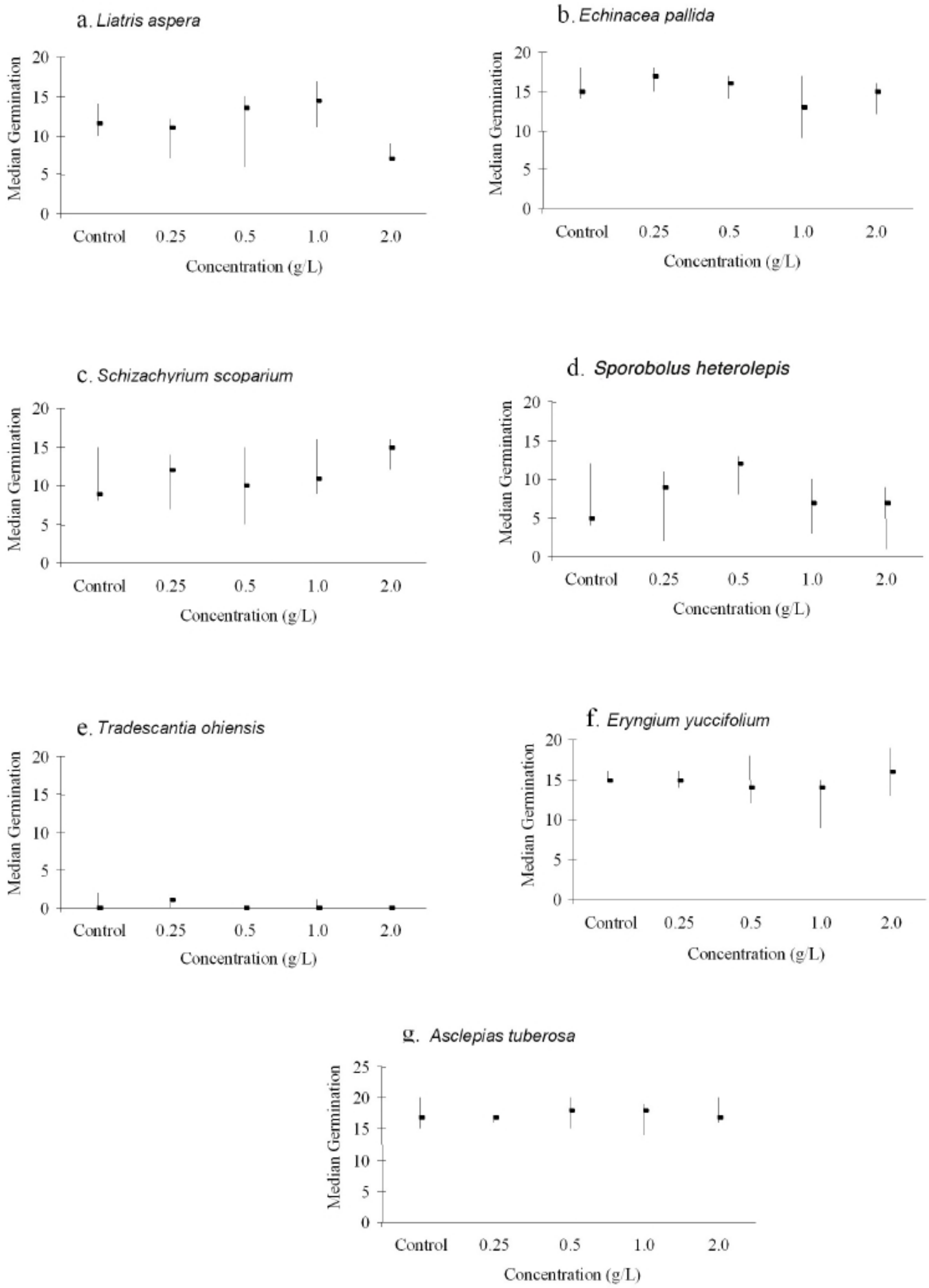

Fig. 2. Percent germination (median ± range) of seven prairie species in field plots in northeastern Illinois with the application of 0 kg/m2, 1 kg/m2, 2 kg/m2, and 3 kg/m2 of road salt. ☐ = statistical significance ($p < 0.05$)