ROAD SALT EFFECTS ON THE GERMINATION OF EIGHT SELECT PRAIRIE SPECIES

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Abstract. Road salt (sodium chloride) as a de-icing agent has destructive effects on roadside vegetation (Dirr 1976, Hanes et al. 1976, Hughes et al. 1975, Westing 1969). This paper uses two greenhouse studies to explore the effects of sodium soil concentration on germination and seedling survival of prairie species. The species tested include buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Canada wildrye (*Elymus canadensis* L.), little bluestem (*Schizachrium scoparium* (Michx.) Nash), Indian grass (*Sorghastrum nutans* L.), roundheaded bushclover (*Lepedeza capitata* Michx.), purple prairie clover (*Dalea purpurea* Vent.), and greyheaded coneflower (*Ratibida pinnata* (Vent.) Barnhart). Sodium concentrations of 0, 500, 1000, 1500, and 2000 ppm for Experiment 1 and 0, 100, 200, 300, and 400 ppm for Experiment 2 were established in a sterilized silt loam soil mix. Germination, survival, stem height, foliage color and biomass data were collected from all species for a period of 8 to 16 weeks. Germination and growth were reduced in all species subjected to Na^+ concentrations greater or equal to 500 ppm. Of the species studied, buffalo grass demonstrated the greatest tolerance of sodium in terms of germination rate and biomass.

INTRODUCTION

The use of native plants along roadways has become a popular alternative to current roadway plantings throughout the Midwest (Harrington 1991). Several states, such as Iowa, Illinois, Minnesota, and Wisconsin, have experimented with native plants to create highly aesthetic, low maintenance ground covers. Accompanying these projects are specific environmental problems created by the unique often artificial habitats in which these species are planted. This study examines one facet of the roadside environment that influences species adaptability; the effects of road salt (sodium chloride) on the germination, survival and health of five grass and three forb species commonly used in roadside restorations.

Between the years of 1970 and 1979, the Wisconsin Department of Transportation undertook a study to determine the extent of salt contamination and accumulation in soils bordering its rural highway systems (Patenaude 1979). Both sodium and chloride concentrations had significant increases within 60 feet of the pavement and accumulated to a greater extent in fine rather than coarse grained soils. In sandy loam soils, sodium levels rarely exceeded 100 ppm while in the silt and clay loams of southeastern Wisconsin levels ranged from 100 to 400 ppm. In more metropolitan areas, such as Chicago, concentrations greater than 20,000 ppm have been found (Hughes et al. 1975, Dirr 1976).

Sodium chloride (NaCl) accumulation in plants affects ionic balances within the cell, as well as osmotic pressures, and normal cellular metabolism (Grueb et al. 1979, Menge and Kirkby 1978, Hanes et al. 1976, Westing 1969). Sodium can produce degrading effects on the soil's physical condition (Singer 1991, Mass 1986, Dorgan et al. 1982). At high concentrations, sodium (Na^+) readily bonds with the soil aggregates allowing clay and humus to disperse into individual hydrated particles instead of remaining flocculated. Soil permeability is decreased through reduced pore space. This impedes drainage, inhibits root penetration, and reduces plant growth.

This research addressed several questions including:

1) What is the relationship between sodium concentrations and the occurrence and timing of germination?

2) What is the relationship between sodium concentrations and height and color of seedlings during the period of the experiment?

3) What is the relationship between sodium concentrations and productivity as described by dried biomass of roots and shoots?

4) Which of the species tested is best suited for saline conditions?

METHODS

Selection of Species

The species were chosen as those commonly used in Wisconsin Department of Transportation roadside plantings, often selected for establishment ease and aesthetic value. Although seven species are native to Wisconsin, buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.) is a western U.S. species regarded as moderately salt tolerant. Buffalo grass was used to compare relative salt tolerance in the other species. The selected native species are: sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), Canada wildrye (*Elymus canadensis* L.), little bluestem (*Schizachrium scoparium* (Michx.) Nash), Indian grass (*Sorghastrum nutans* (L.) Nash), roundheaded bushclover (*Lepedeza capitata* Michx.), purple prai-

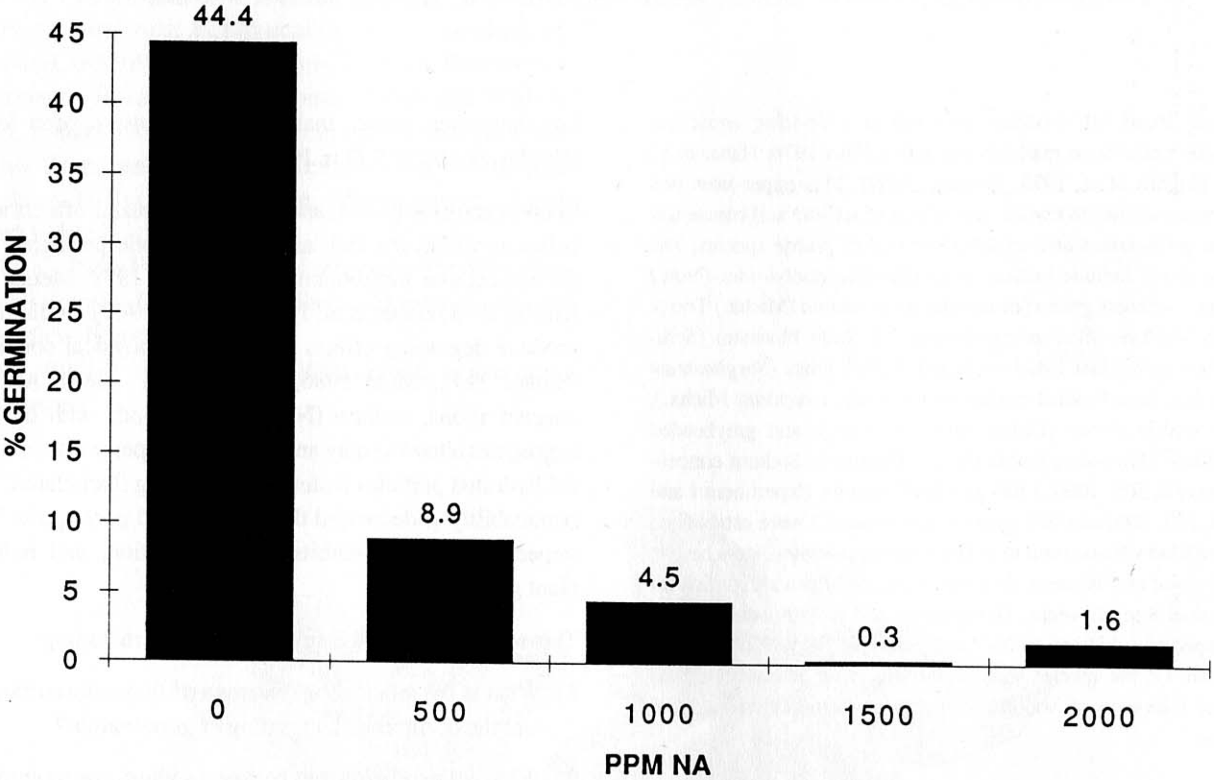


Figure 1. Cumulative germination rates for all species at Na^+ concentrations of 0, 500, 1000, 1500, and 2000 ppm.

rie clover (*Dalea purpurea* Vent.), and greyheaded coneflower (*Ratibida pinnata* (Vent.) Barnhart).

Experimental Design

Species were planted in six-inch plastic pots and represented by four replications of each Na^+ concentration within each study. Seeding density was at 5, 10, and 15 seeds per pot. Each species was planted at two of these densities to test for any influences of seeding density on germination. None was found. Densities used were based on recommendations by Rock (1977). The studies were set up as a randomized block design.

Silt loam soil was chosen as the planting substrate due to its ability to limit leaching of salts. The soil was sterilized for 1-1/2 hours at 108°C and 9.5 psi in an autoclave. Dispersion point was calculated at 690 ppm Na^+. This calculation, determined at the UW Soils Lab, is based on the soil's clay type, montmorillonite, and a 20% displacement of cation exchange capacity with Na^+ leading to dispersion. The amount of NaCl needed to raise the Na^+ in all pots to desired concentrations was calculated using the equation:

$$\text{mg NaCl to add/kg oven dry soil} = \frac{\text{ppm } Na^+ \text{ desired}}{\text{kg oven dry soil/pot}}$$

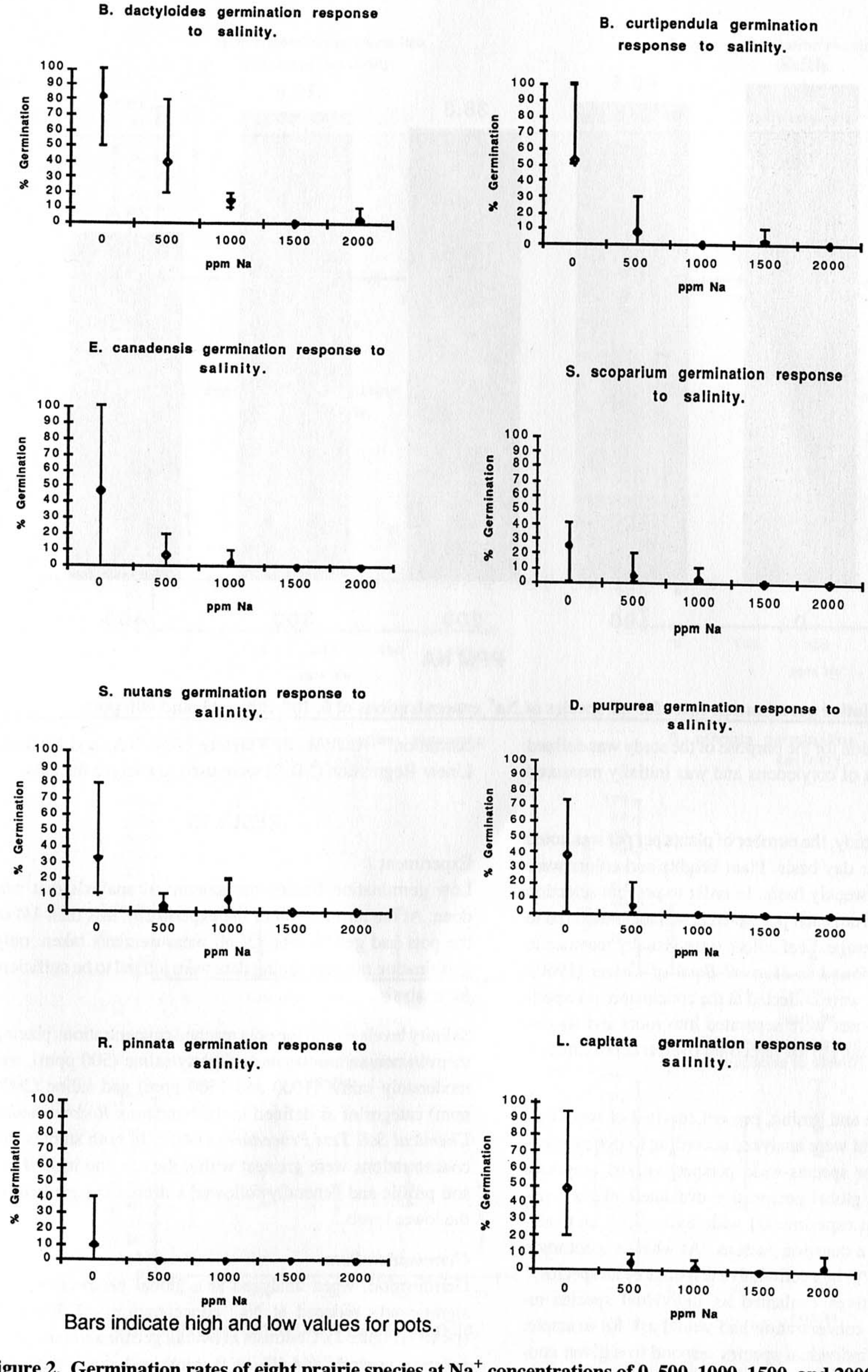
and added to distilled water for application.

Species were planted in soil with sodium concentrations of 0, 500, 1000, 1500, and 2000 ppm for the first study. Plants were grown for a total of eighteen weeks. The second study was conducted to test species at concentrations of 0, 100, 200, 300, and 400 ppm Na^+. These concentrations are typical of those found in a rural Wisconsin setting. This study lasted for a total of eight weeks. All soils at concentrations above 500 ppm Na^+ would be expected to experience dispersion.

Seed was dry stratified and all legumes inoculated with *Rhizobium* bacteria. 1500 grams of moist soil was added to each pot. The pots were lined with polyethylene bags intended to prevent leaching and promote germination. After seeding pot surfaces were gently packed, 50 milliliters of the appropriate salt solution was added and the top of the polyethylene bag was tied to prevent drying of the surface. The daily amount of water to be added was based on soil weight.

Data Collection

Measurements taken were for germination rate, survival, height, foliage color, biomass, and soil salinity. Soil samples were dried for 48 hours at 60° C in a forced-air oven and ground to a consistent grain size before tested using a YSI Model 31 Conductivity Bridge to determine salinity. Soil salinity was measured using the 1:1 soil:water method following *Recommended Chemical Soil Test Procedures*



Bars indicate high and low values for pots.

Figure 2. Germination rates of eight prairie species at Na^+ concentrations of 0, 500, 1000, 1500, and 2000 ppm.

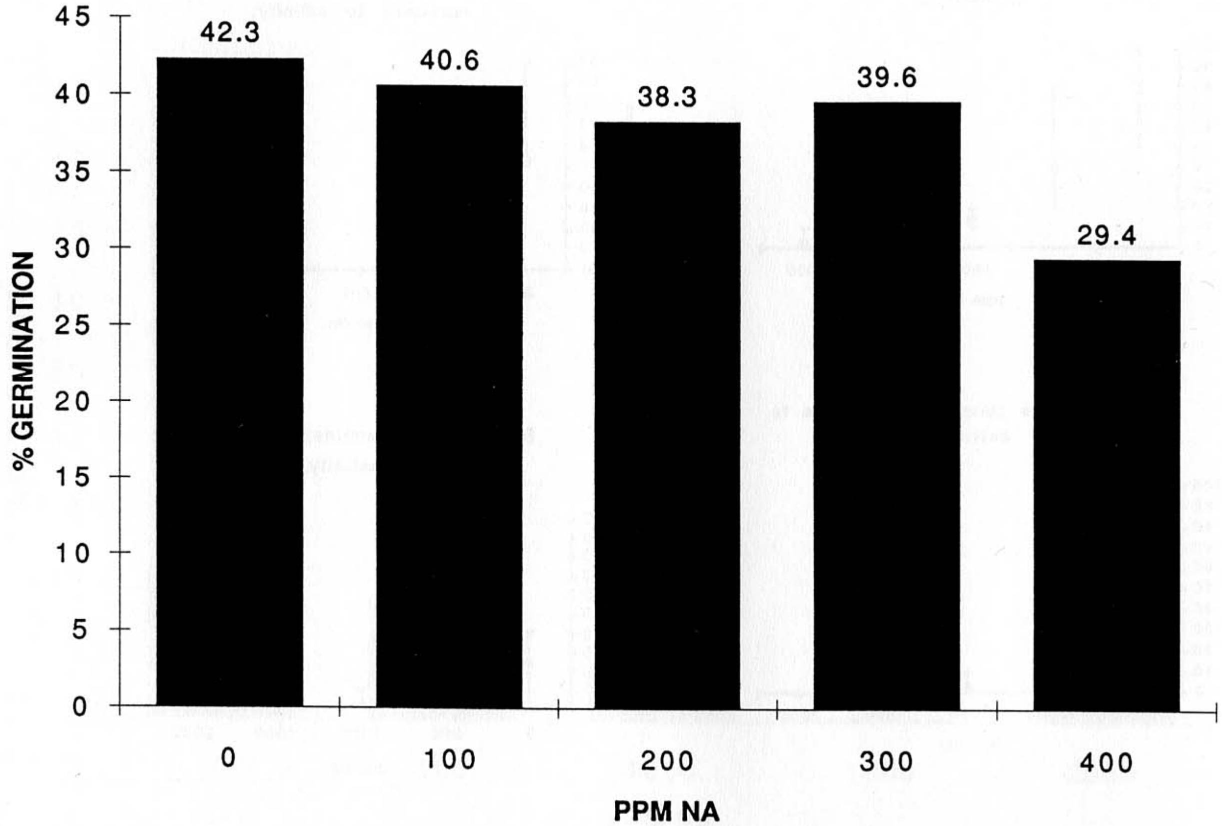


Figure 3. Cumulative germination rates for all species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

(1988). Germination for the purpose of the study was defined as the emergence of cotyledons and was initially measured on a daily basis.

Throughout the study, the number of plants per pot was noted on an every other day basis. Plant heights and colors were determined on a weekly basis. In order to prevent selection bias, five plants from each pot were chosen and measured to give a sample average. Leaf colors were visually matched to the color plates found in *Munsell Book of Colors* (1960). Biomass samples were collected at the conclusion of Experiment 2. Plant tissues were separated into roots and shoots, and dried for 48 hours in the forced-air oven at approximately 60° Celsius.

Germination rate and timing, percent survival of seedlings, and average height were analyzed according to two perspectives: a global or species-wide perspective and a species perspective. The global perspective evaluated all Na^+ concentrations on an experimental wide basis. Such an evaluation would ask a question such as "At what concentration does there appear to be a cumulative response by all species?" Species perspectives evaluated an individual species response to a Na^+ concentration and would ask for example, "How does this individual species respond to a given concentration?" Analysis of Variance (ANOVA) and Multiple Linear Regression (MLR) were used to analyze the data.

RESULTS

Experiment 1

Low germination limited the amount of analysis that was done. At the termination of the experiment, less than 1/4 of the pots had germinants. Of all measurements taken, only germination rate and timing data were judged to be sufficient for analysis.

Salinity levels within the pots reached concentrations placing them in non-saline (0 ppm), slightly saline (500 ppm), and moderately saline (1000 and 1500 ppm) and saline (2000 ppm) categories as defined in the handbook *Recommended Chemical Soil Test Procedures* (1988). In both studies salt concentrations were greatest within the top one inch of the soil profile and generally followed a decreasing gradient to the lower levels.

Germination Rate

Germination, when analyzed at a global perspective, was significantly reduced at Na^+ concentrations of 500 ppm ($p<.01$) (Figure 1). Contrasts in overall germination occurred between controls (44.4% at 0 ppm) and the lowest salt

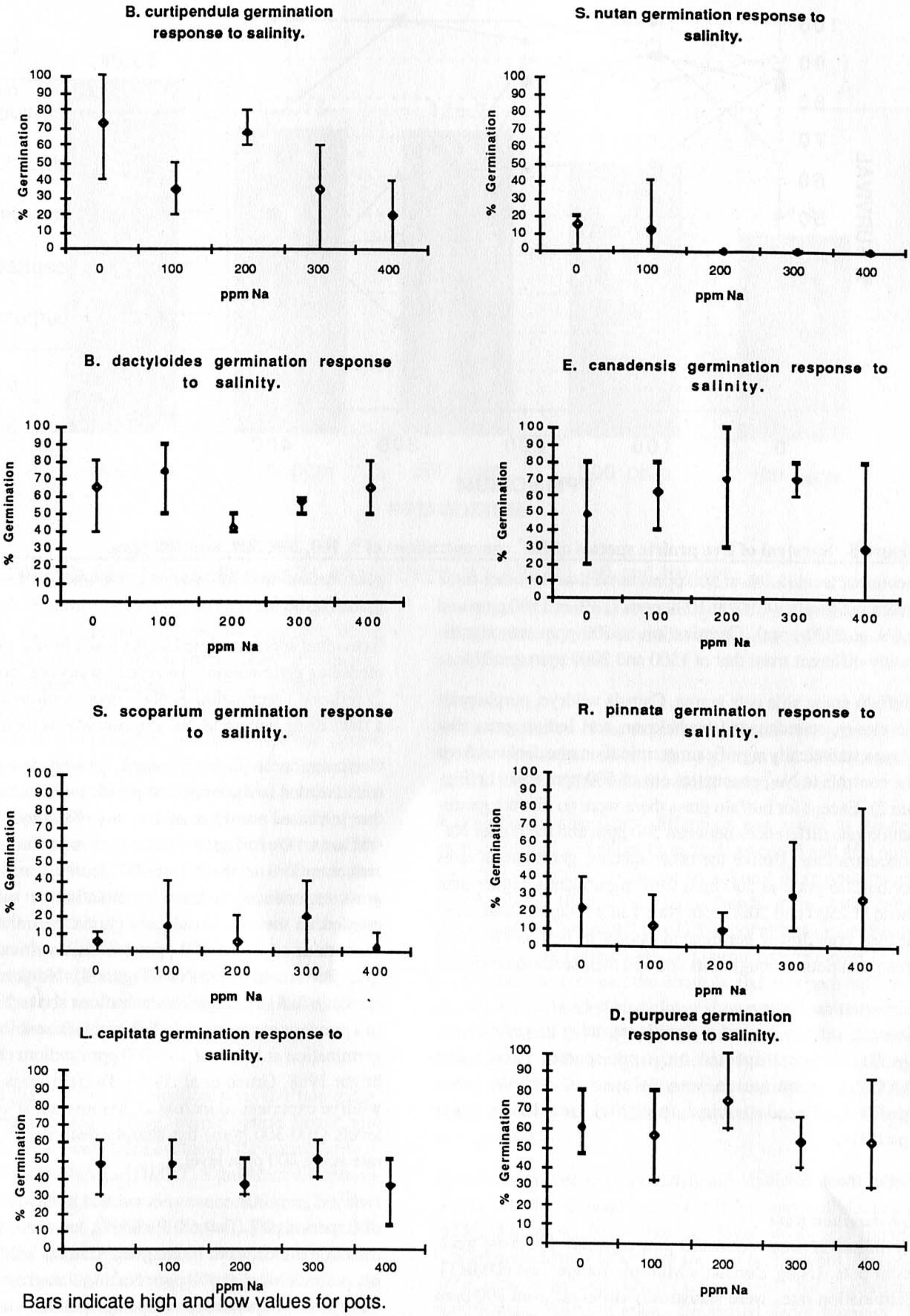


Figure 4. Germination rates of eight prairie species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

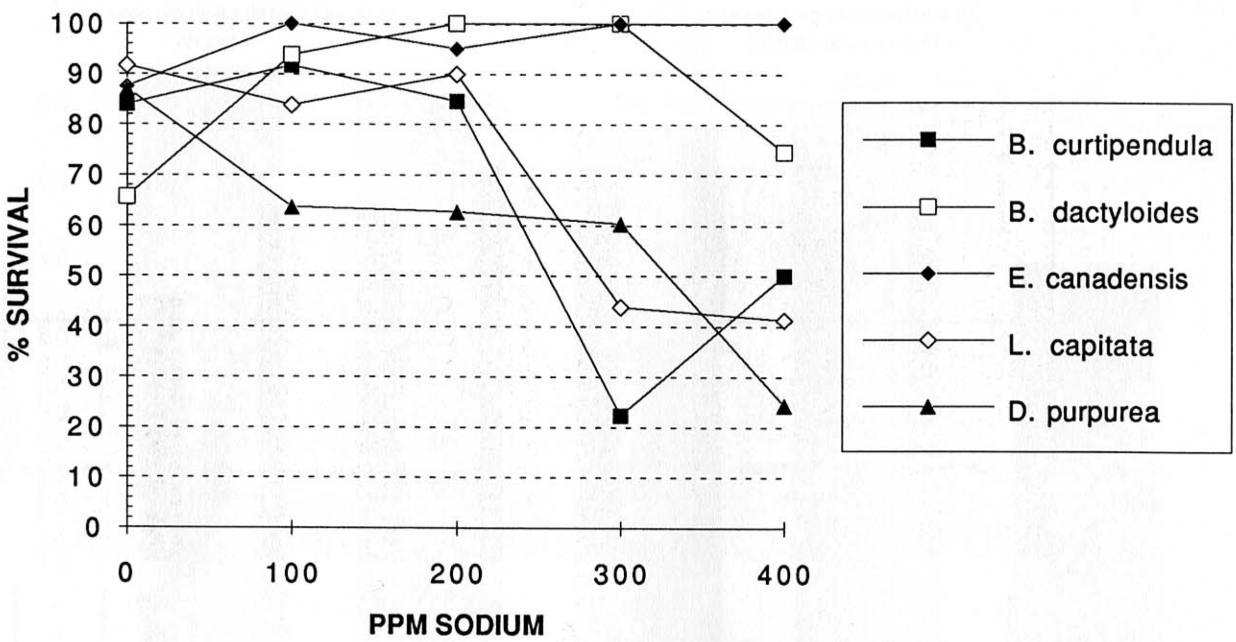


Figure 5. Survival of five prairie species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

treatment level (8.9% at 500 ppm) as well as the other three treatment levels; (4.5% at 1000 ppm, 0.3% at 1500 ppm and 1.6% at 2000 ppm). Germination at 500 ppm was significantly different from that at 1500 and 2000 ppm ($p<.01$).

Buffalo grass, side oats grama, Canada wildrye, purple prairie clover, roundheaded bushclover, and Indian grass displayed statistically significant germination rate declines from the controls to Na^+ concentrations of 500 ppm ($p<.01$) (Figure 2). Except for buffalo grass there were no distinct germination rate differences between 500 ppm and the higher Na^+ concentrations. Unlike the other species, germination rates for buffalo grass at 500 ppm were significantly higher than those at 1500 and 2000 ppm Na^+. Little bluestem and greyheaded coneflower germinated poorly in both control and treatment pots although tests showed their seeds to be viable.

Germination Timing

Overall, salinity caused a significant delay in germination ($p<.01$). When inspected on a per species basis using ANOVA, germination was delayed in buffalo grass ($p=.0004$), Canada wildrye ($p=.0001$), and Indian grass ($p=.0001$).

Experiment #2

Germination Rate

Germination occurred in 133 pots of which 102 were treatment pots. Using Duncan's Multiple Range Test (DMRT), germination rates were statistically different from 300 ppm to 400 ppm ($p<.05$). There were no significant differences in germination rates for species in treatments of 0 ppm to 300 ppm (Figure 3).

Individual species reacted to the NaCl in one of three ways regarding germination: 1) no effect at any Na^+ concentration; 2) reduced germination as Na^+ concentrations increased; 3) a fluctuating pattern as Na^+ concentrations increased.

Germination in little bluestem, greyheaded coneflower, roundheaded bushclover, and purple prairie clover was neither increased nor decreased by any of the soil Na^+ concentrations. Germination appears unaffected by Na^+ concentrations at these levels. Sideoats grama and Indian grass experienced reduced germination as salt levels increased. In the case of sideoats grama, germination at concentrations of 0 and 200 ppm Na^+ is statistically different ($p<.05$) from 400 ppm Na^+ (Figure 4). No germination occurred in Indian grass at concentrations above 200 ppm Na^+. In a previous experiment, Indian grass also exhibited reduced germination at levels of 100-200 ppm sodium chloride (Fulbright 1988, Grueb et al. 1979). Buffalo grass and Canada wildrye experienced increased germination at very low Na^+ levels (100-300 ppm) but sharply declined in germination rate at the 400 ppm level.

Delayed germination was not evident in the overall analysis of Experiment 2 ($F=0.68$, $P=.8517$), however, delayed germination did occur in Indiangrass, Canada wildrye and purple prairie clover at 400 ppm Na^+. Indian grass and Canada wildrye also experienced delayed germination in Experiment 1.

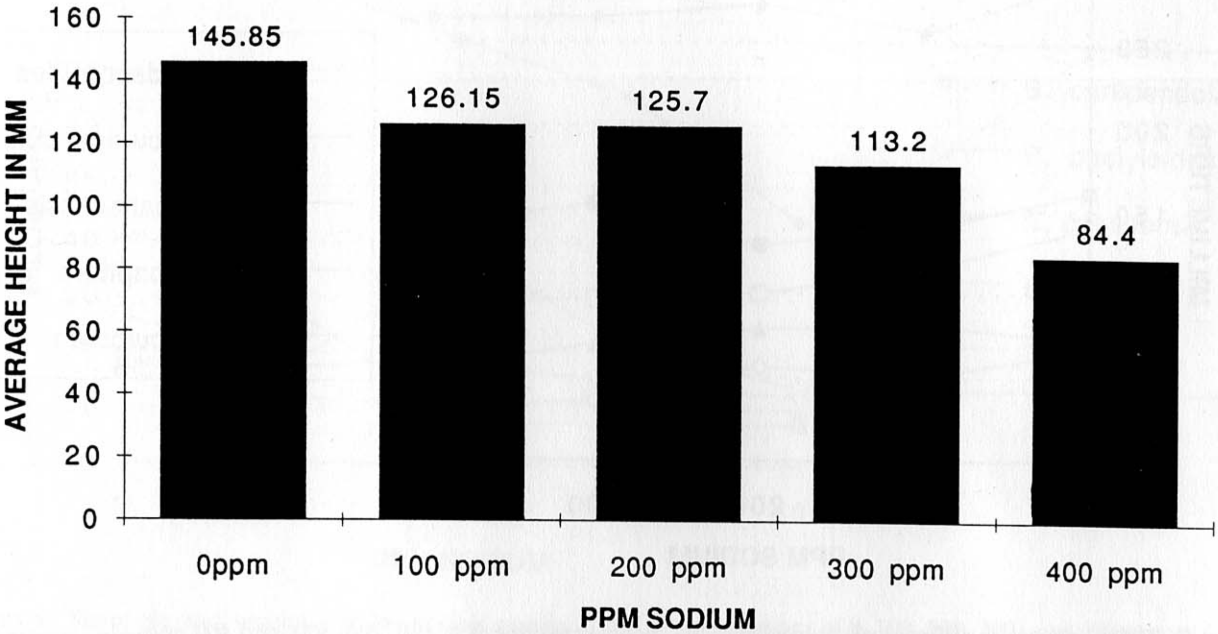


Figure 6: Cumulative height for all species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

Using DMRT, seedling survival was statistically different at 400 ppm Na^+ from all lower concentrations ($p<.01$). When considering survival of individual species after germination no trends were observed for Canada wildrye, little bluestem and greyheaded coneflower. Seedling survival was significantly reduced at 400 ppm Na^+ ($p<.05$) for purple prairie clover, and roundheaded bushclover (Figure 5). Buffalo grass seedlings had their highest survival at Na^+ levels of 200 ppm and 300 ppm and their poorest at 0 ppm and 400 ppm. Sideoats grama survived best at 100 ppm and poorest at 300 ppm and above. Levitt (1980) and Waisel (1972) note that several species require sodium as an essential element in low amounts while Larcher (1983) found several halophytic grasses to absorb sodium into the roots in order to increase osmotic potential and thus, potential for water absorption. Indian grass had no survival at 400 ppm. No foliage color changes were visually identified.

Height

Species with the top five germination rates (buffalo grass, sideoats grama, Canada wildrye, purple prairie clover, and roundheaded bushclover) were evaluated for overall growth of shoots using ANOVA and DMRT. Significant differences ($p<.05$) in total growth occurred between 400 ppm Na^+ and all other concentrations (control, 100 ppm, 200 ppm and 300 ppm) on a global scale (Figure 6). At the end of six weeks, salinity levels had significantly affected the heights of sideoats grama, purple prairie clover, and roundheaded bushclover (Figure 7). Purple prairie clover was reduced by 23% in height between controls and 400 ppm Na^+ and roundheaded bushclover was reduced by 55% over the same interval. Sideoats grama was reduce 32% in height between the controls and 400 ppm.

Biomass

At the conclusion of the experiment, the top five germinated species were separated into above ground and below ground parts to test for differences in dried weight biomass.

A statistically significant difference was noted in the responses of root and shoot biomass between 0 and 400 ppm Na^+. Root biomass decreased as salinity increased for all species tested (Figure 8). These trends were statistically significant for Canada wildrye (75% root reduction), sideoats grama (44% root reduction), and purple prairie clover (31% root reduction) between the controls and 400 ppm Na^+ and greater. Roundheaded bushclover showed obvious reduction in root biomass (64%), however, due to a small sample size this was not statistically significant. Buffalo grass was reduced only 8% between the controls and 400 ppm and the plants growing at 100 ppm Na^+ actually increased 22% in root biomass.

Shoot biomass decline was statistically significant in sideoats grama (55 %), Canada wildrye (49%), and buffalo grass (47%) (Figure 9). Purple prairie clover (46%) and roundheaded bushclover (34%) both showed declines but the variance was large and samples too small for statistical significance. Sideoats grama (increased shoot biomass of 60% between 0 ppm and 100 ppm Na^+) and buffalo grass (increased shoot biomass of 44% between 0 ppm and 200

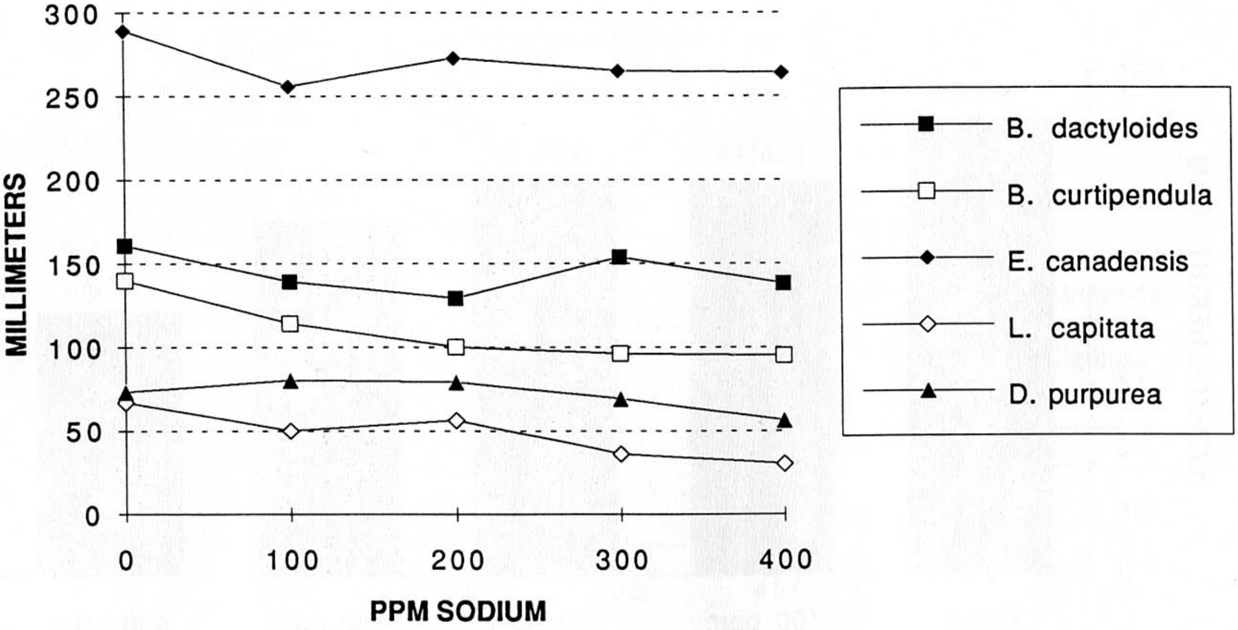


Figure 7. Height response of five prairie species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

ppm Na^+) showed stimulated shoot production at low salt levels.

CONCLUSIONS

Slightly saline conditions appear to affect the germination and early survival of prairie grasses and forbs. Germination, survival, overall height, and biomass each declined in all species at 500 ppm Na^+ and for some species at 400 ppm. Some species such as buffalo grass and sideoats grama appear to respond with increased germination and seedling survival at low salt levels of 100-200 ppm. This response may reflect the ability of some species to tolerate or utilize assimilated salts to their advantage. Although many species did not show statistically significant declines in germination rates at 400 ppm they did show germination delays. Indian grass, Canada wildrye and purple prairie clover each experienced delayed germination at Na^+ concentrations of 400 ppm and greater.

Once germinated many seedlings persisted although growth was slow and productivity as defined by biomass was re-

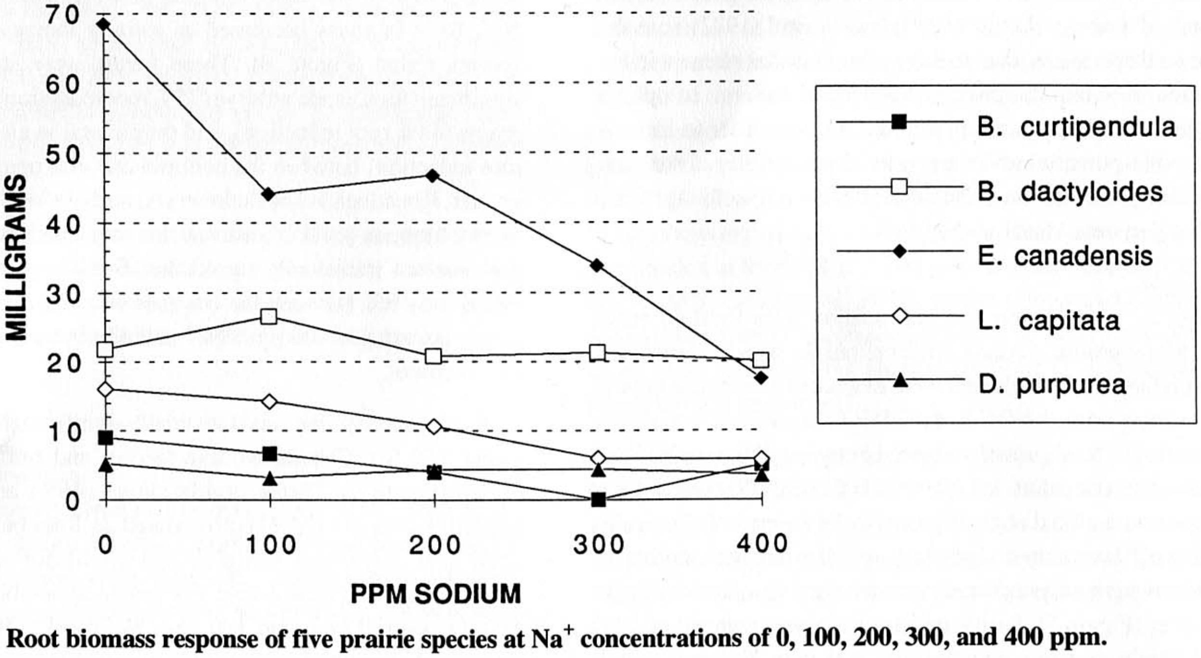


Figure 8. Root biomass response of five prairie species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

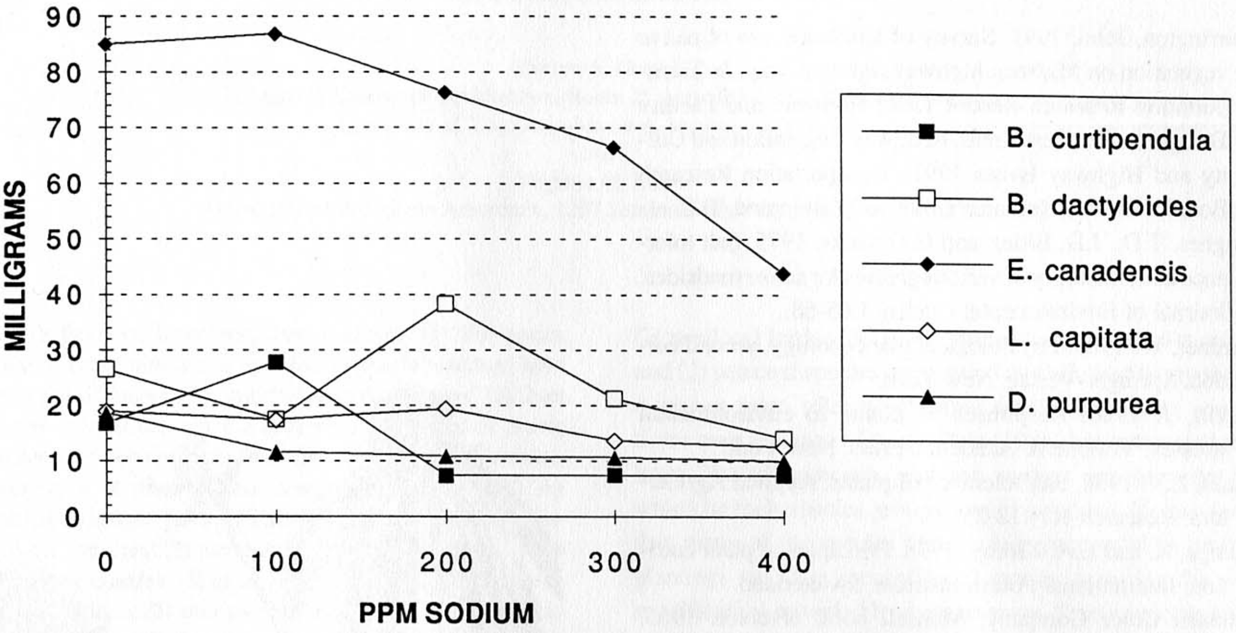


Figure 9. Shoot biomass response of five prairie species at Na^+ concentrations of 0, 100, 200, 300, and 400 ppm.

duced. Canada wildrye and buffalo grass appear to have the greatest tolerance to Na^+ of the species tested. Canada wildrye, in particular, demonstrated no loss of seedlings at 400 ppm Na^+. Both species had no decline in height at 400 ppm. Buffalo grass had no loss in root biomass and little in shoot biomass. Buffalo grass also had the least decline in germination of any species tested. On the other hand, Indian grass demonstrated the least tolerance of Na^+ when the measures of germination and seedling survival are considered.

The results of this study suggest the need for much more research. During the course of the study, the exact causes (osmotic potential, soil degradation, or direct toxic effect) of the responses were not determined. Soil dispersion and toxic effects, as might be indicated by foliage color, were not apparent. Changes in osmotic potential that affect water and nutrient uptake, although not investigated, are likely candidates for germination delays and, in the case of buffalo grass and sideoats grama, improved growth and survival (Unger 1982). Root depth was not studied, however, Na^+ declines with soil depth. For species that can quickly establish feeder roots below highly concentrated salt zones, road salt may not be a significant problem. This may be a factor why some seedlings of species in the study had high survival.

A second and essential need for further study is the confirmation of these results under field conditions. Larger soil volumes, weather patterns, differences in soil texture, presence of organic matter, and interspecies relations may all effect a species response to salinity. We have not initiated field experiments on germination. We are, however, conducting field experiments for Na^+ effects on established three year old plants of these species. Many more native species commonly used along roadsides also must be tested. Although this study evaluated eight species, the Wisconsin Department of Transportation currently uses forty-two species within plantings and plantings up to 70+ species are feasible and desired (Wisconsin Department of Transportation 1990). Finally, individual species must be examined for salt tolerance within their respective gene pools. Perhaps in areas where prairie species commonly grow along roadsides, selection for salt tolerance has occurred.

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