

EFFECTS OF SODIUM CHLORIDE ON *BRASSICA RAPA*

(WISCONSIN FAST PLANT™)



BY

CODY ADKINS

DIAMOND ALEXANDER

JOSEPHINE BECKMAN

SUMMYR BUTTS

MARCUS GAINES

DAVID HUFFER

JESSICA HURTT

TAMMY JOHNS

DEMETRIUS SAUNDERS

LASHAWN SMITH

ARCACIA STEPNEY

TRAVIS STROUD

WAHLIA WALKER

KAYLYN WALLS

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TEACHERS: JESSICA BRANDT, JENNIFER BOHRMAN AND MANDY VANDIVIER

TCS: BENJAMIN ALLEN AND KELSEY DENNIS

INTRODUCTION

Soil is important to plants because it provides the water and minerals needed for growth. Soil contains nutrients and minerals necessary for plant growth, such as potassium (K), phosphorous (P), nitrogen (N), and calcium (Ca) (Keeton, 1980). These minerals are only available when dissolved in water. When the plants take in the water through the root system these minerals are absorbed. The structure of soil is important to plants because it affects the availability of water; the larger the particles in the soil, the less water that can get to the plants because less water is retained by the soil. The water will not be available in the soil and will deprive the plants of nutrients (D'Ambrosio, Lawrence, & Brown 2004).

Soil is severely impacted by urbanization. Urbanization is the construction of buildings and cities. One way that urbanization affects soil is by compacting it. Compacted soil is packed tightly in the ground and prevents nutrients, minerals, and water from getting to the plants' root systems. In addition, urban areas have large amounts of impervious surfaces. An impervious surface is an area through which water cannot flow; examples include concrete or asphalt. When water moves over the impervious surfaces, the water picks up pollutants, such as salt, and deposits them into soil. This is known as runoff. Such pollutants can harm plants and create a reduction in vegetative cover (Committee on the Comparative Costs of Rock Salt & Calcium Magnesium Acetate, 1991).

Salt is a common pollutant in urban areas. Road salt is used as a deicer during ice and snow events (Committee on the Comparative Costs of Rock Salt & Calcium Magnesium Acetate, 1991). Highways and high traffic roads have high priority; they are treated with salt most frequently and intensely. Salt, applied to roads, eventually is deposited into soil by runoff.

When in water, road salt, (sodium chloride), separates into two different components, sodium (Na^+) and chloride (Cl^-), and each affects the plants in different ways. Sodium decreases soil permeability, which reduces the flow of water to the plants possibly affecting germination. Sodium increases compactness of soil limiting the soil's ability to retain water and nutrients. While sodium is not absorbed by plants, chloride is. Chloride is thought to be more harmful directly to plants than sodium absorbed through roots. Over time chloride accumulates in plant tissues causing damage and reducing growth. Chloride increases the mobility of heavy metals, such as iron and cadmium, in soil. Toxic heavy metals are taken up by plants, damaging tissue and reducing health. Chloride can dehydrate plants through osmotic stress. Osmotic stress is when water is excreted from the roots to maintain the same concentration of ions inside the plant as in the soil. Osmotic stress decreases the amount of nutrients taken up by plants slowing growth and development (Taiz, & Zeiger, 2006). Dehydration causes plants to allocate more energy to the root system growth because the plant focuses on extending its roots further down to find water; therefore, less energy is used for the leaves and shoots. The presence of sodium and chloride in soil reduces the amount of water and nutrients taken up by plants, thus height, germination success, number of leaves, and biomass of the plants are reduced (Committee on the Comparative Costs of Rock Salt & Calcium Magnesium Acetate, 1991).

Different types of plants react differently in saline soils. Halophytes and glycophytes are two types of plants that differ in their reactions to saline soils. Halophytes are plants that are tolerant of salt. Examples of halophytes are cotton, honeysuckle, white ash, Siberian elm, and hedge maple. Glycophytes are plants that are intolerant of salt. Examples of glycophytes are maize, rice, citrus, pecans, and lettuce (Taiz, & Zeiger, 2006). The impact of salt on glycophytes

is, decreased germination success, height, weight, and dehydration (Center for Watershed Protection, 1995).

This experiment examined the effect of sodium chloride on the germination and growth of glycophytes, *Brassica Rapa* (Wisconsin Fast Plants™). Four different soil salinity levels were tested, non-saline, slightly saline, moderately saline, and strongly saline. Soil salinities were chosen based on the electrical conductivity of the saturated paste column on the Montana NRCS Soil Salinity Classes chart. Germination success, height, weight, number of leaves, and root length will be measured to assess the impact of sodium chloride on Wisconsin Fast Plants™. Wisconsin Fast Plants™ were chosen because they grow quickly and are easy to study. Visual observations such as discoloration, wilting, and asymmetrical leaves will be recorded. It was hypothesized that if the sodium chloride concentration in soil increases, then the development and growth of the Wisconsin Fast Plants™ will be inhibited.

METHODS

This experiment was conducted between July 2, 2009, and July 14, 2009, in Compton 225 on the Frostburg State University campus. The experiment was conducted over an 11-day period. On July 2, 2009, one Wisconsin Fast Plant™ seed was planted in each section of five Styrofoam quads for each treatment group, making a total of 80 plants. The treatment groups were: non-saline, slightly saline, moderately saline, and strongly saline soil. The non-saline treatment had a soil salinity of 0 dS/m. The slightly saline treatment had 6 dS/m. The moderately saline soil contained 12 dS/m, and the strongly saline soil contained 24 dS/m. To achieve these soil salinities, dry potting soil was saturated with the treatment sodium chloride concentration. The different amounts of sodium chloride were added to 1 liter of deionized water. The non-

saline treatment contained 0g/L of sodium chloride; the slightly saline treatment contained 4.2g/L of sodium chloride; the moderately saline treatment contained 8.4g/L of sodium chloride, and the strongly saline treatment contained 16.8g/L of sodium chloride. The conversion factor from dS/m to g/L is 1dS/m= .7 grams of sodium chloride per one liter of water was used.

Wisconsin Fast Plants™ were grown using the instructions from the Carolina Biological Supply Company. Each quad was filled three quarters of the way with soil, and then a seed and a fertilizer pellet were placed in the middle of the soil and covered with another thin layer of soil. The soil was saturated with the treatment saline solution and then the quads were placed on a self-watering system (*Figure 1*). A container was filled halfway with tap water. A felt cloth was placed over the lid of the container with the end of the cloth resting in the water. Through capillary action, the entire cloth became moist. The quads were set on top of the moist cloth with a wick in the bottom in order to transfer water from the cloth to the soil. The Wisconsin Fast Plants™ were stored at room temperature and placed under a florescent light 24 hours a day (Carolina Biological Supply Company, n.d.). The light was placed 10 cm above the quads.

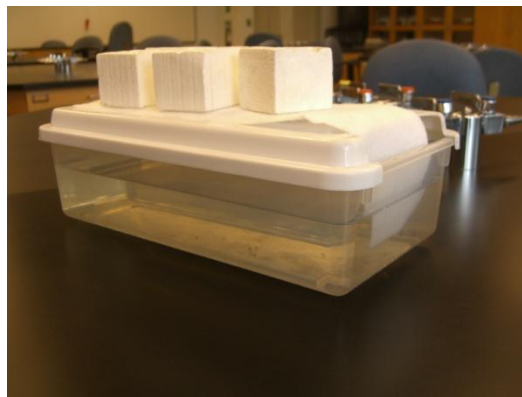


Figure 1. Wisconsin Fast Plant™ self-watering system.

On Days 4, 5, and 6, the plants' heights, number of leaves, and germination success were recorded. Visual observations such as discoloration, wilted leaves, and dry soil were also recorded on Days 4, 5, and 6. On Day 11, the height and number of leaves of each plant were recorded, as well as the mass in grams, the germination rate, and the root length in centimeters. The height of the plant was recorded from the surface of the soil to the tallest part of the stem. The mass of each plant was measured by removing the plant from its soil, cleaning it off, removing the root system, and massing it with an electronic balance. To find root length, plants were removed from the soil and cleaned off, and a ruler was used to record the length. Plants were dehydrated overnight to take the dry mass in grams. Final mass and dry mass will be used to calculate the percentage of water retained. The plants were cleaned off before massing so that just the plant was being massed.

The data collected throughout this study was compiled into a data table with daily measurements, visual observations, and averages. Data were compiled into five graphs showing mean height, mass, germination, root length, and number of leaves for each treatment. A one-way ANOVA was run to compare the average final height, number of leaves, and the germination rate among the four treatments. ANOVAs were one tailed for germination, height, mass and number of leaves and two tailed for root length. A Tukey test was run to determine between which treatments there were significant differences. The alpha value was set at .05.

After conducting the experiment in the Compton Science Center, soil was collected outside of Compton in three different locations. Two samples were collected from sites located alongside a commonly used salt impacted sidewalk. The first sample was on the downhill side of the sidewalk. The second was on uphill side of the sidewalk which received less runoff. The third sample was taken from a grassy area on a hill 10 meters from the sidewalk. The soil was mixed

with water in a 1:2 dilution. Fifty grams of soil from each sample were mixed with 100g of de-ionized water. An electric conductivity meter was used to find the salinity in the soil in dS/m. Deciseimens are the unit of measure for conductivity of ions in soil. Soil salinities were classified using the 1:2 dilution soil column of the salinity classes' chart (United Sates Department of Agriculture: Natural Resources Conservation Service, 2008).

RESULTS

The visual observations noted that all of the plants in the non-saline treatment appeared healthy, and there were no abnormalities or discoloration. In the slightly saline treatment, 20% of the plants had dry soil, asymmetric leaves, or discoloration. In the moderately saline treatment, 30% of the plants had yellow and asymmetrical leaves, folded or red tipped leaves or were dehydrated. In the strongly saline treatment, 100% of the plants exhibited discoloration, wilted leaves and stems, or asymmetrical leaves.

Germination was delayed and growth was inhibited in the strongly saline treatment. On Day Four, the germination success of the plants grown in the strongly saline treatment was significantly less than the germination success of the plants grown in the non-saline and slightly saline treatments (*Figure 2a*). By Day 11, however, there was no significant difference in germination success of the plants grown in the strongly saline treatment when compared to the germination success of the plants grown in the non-saline and slightly saline treatments (*Figure 2b*). In addition, the number of leaves, height, and mass of the plants grown in the strongly saline soil were significantly lower than number of leaves, height, and mass of the plants grown in the non-saline, slightly saline, and moderately saline soils (*Figure 3, 4, and 5*). The root length of the plants grown in the strongly saline treatment was significantly shorter than the root length of the plants grown in the non-saline and moderately saline treatments (*Figure 6*).

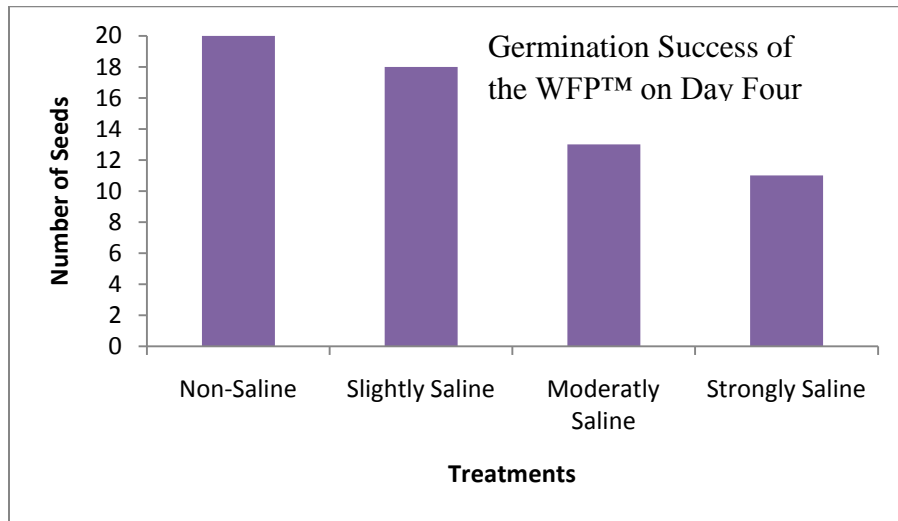


Figure 2a. The number of Wisconsin Fast Plants™ germinated in each soil salinity treatment.

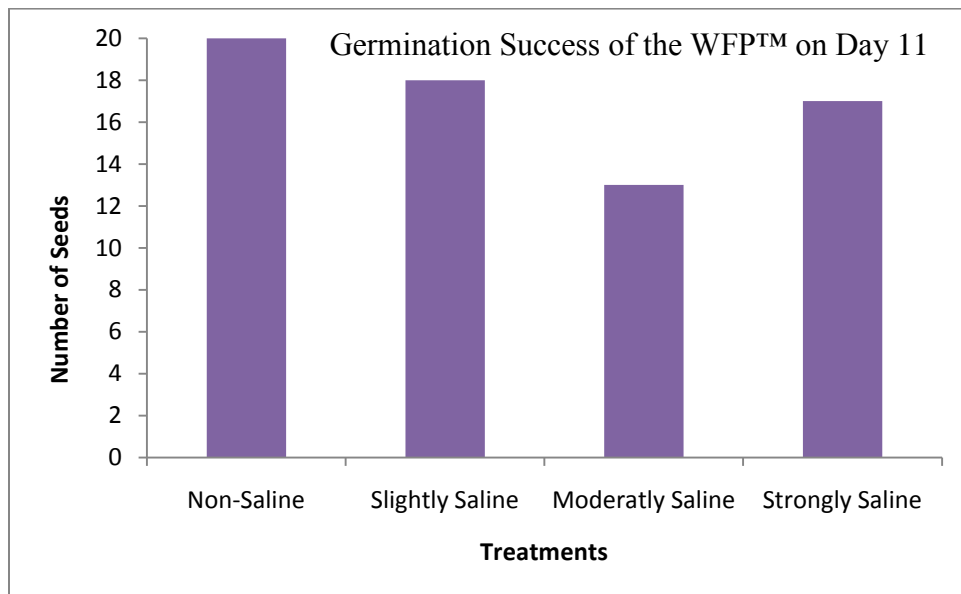


Figure 2b. The number of Wisconsin Fast Plants™ germinated in each soil salinity treatment.

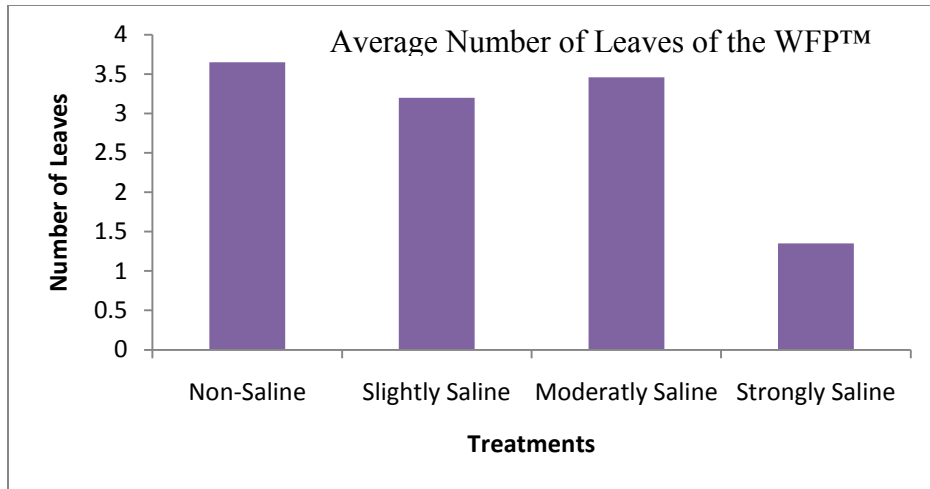


Figure 3. The average final number of leaves on the Wisconsin Fast Plants™ in each soil salinity treatment.

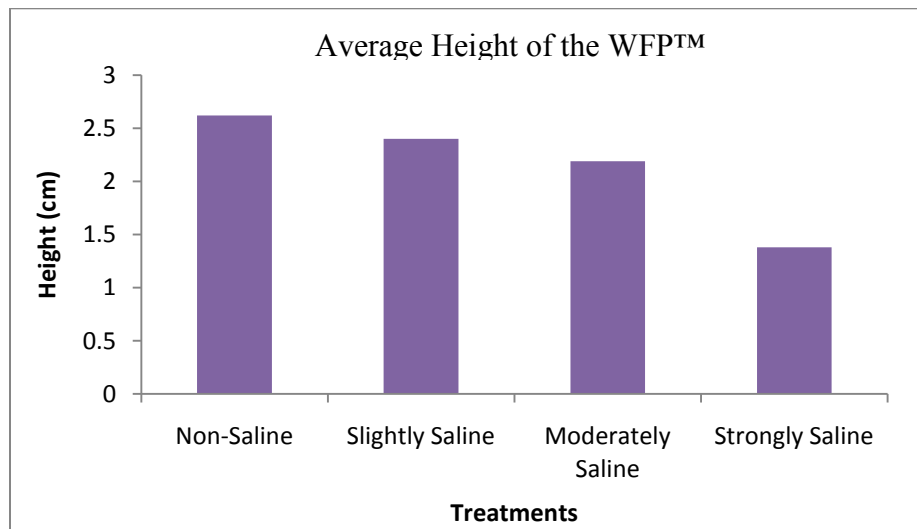


Figure 4. The average final height of the Wisconsin Fast Plants™ in each soil salinity treatment.

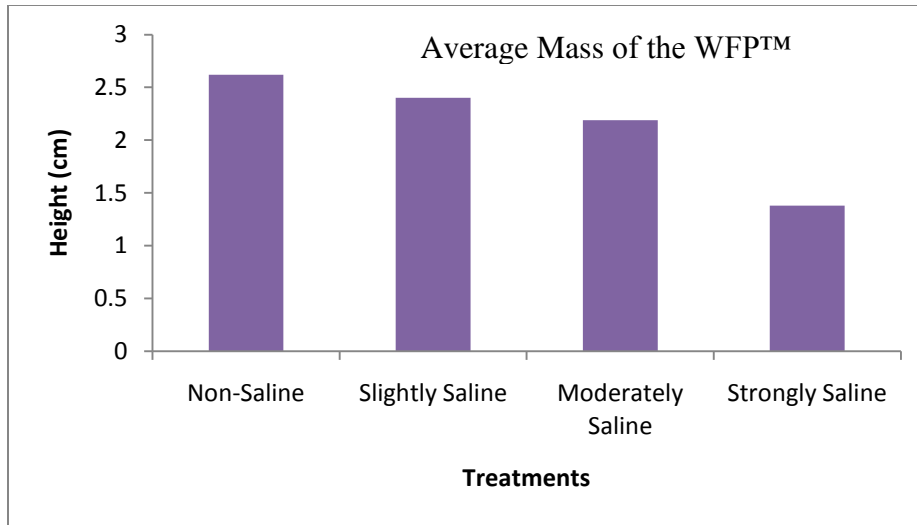


Figure 5. The average mass in grams of the Wisconsin Fast Plants™ in each soil salinity treatment.

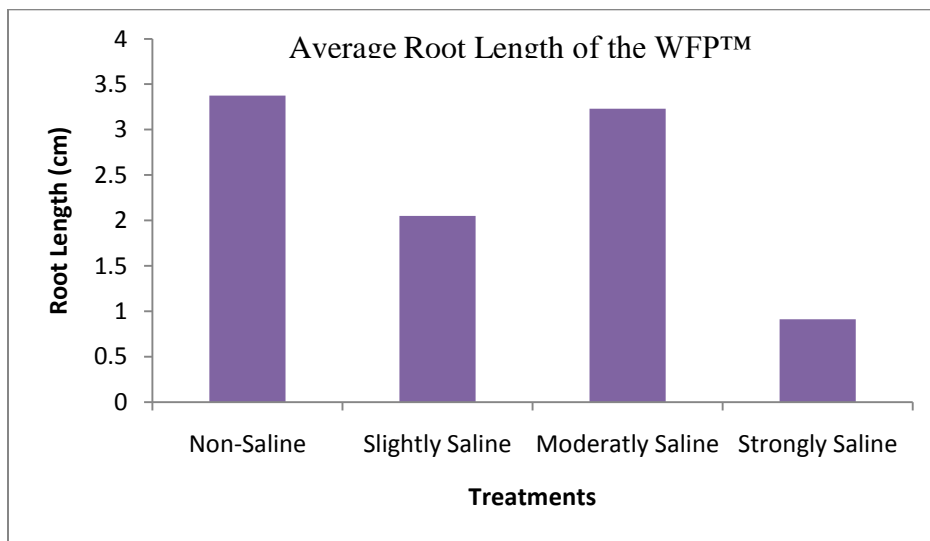


Figure 6. The average root length of the Wisconsin Fast Plants™ in each soil salinity treatment.

The non-saline treatment had a germination success of 20 plants ($SD = 0$); the slightly saline treatment had a germination success of 18 plants ($SD = .31$); the moderately saline treatment had a germination success of 13 plants ($SD = .49$); the strongly saline treatment had a germination success of 17 plants ($SD = .57$). The effect of sodium chloride on germination

success was significant, $F(3, 76) = 3.70, p < .02$ (one-tailed). A significant difference at alpha level of .05 in germination was found between the non-saline and the moderately saline treatments, $p < .01$.

The average number of leaves on the Wisconsin Fast PlantsTM in the non-saline treatment was 3.65 ($SD = .49$); in the slightly saline treatment, the number of leaves was 3.20 ($SD = .62$); in the moderately saline treatment, the number of leaves was 3.46 ($SD = .52$), and in the strongly saline treatment, the number of leaves was 1.35 ($SD = .86$). The effects of sodium chloride on number of leaves was significant, $F(3, 68) = 20.11$ (one-tailed). A significant difference at the alpha level of .05 was identified in height between the non-saline and strongly saline treatments, ($p < .01$), slightly saline and strongly saline treatments, ($p < .01$), and moderately saline and strongly saline treatments, ($p < .01$).

The 20 plants in the non-saline treatment had an average height of 2.54cm ($SD = .57$); the 18 plants in the slightly saline treatment had an average height of 2.40cm ($SD = .78$); the 13 plants in the moderately saline treatment had an average height of 2.19cm ($SD = .52$); the 17 plants in the strongly saline treatment had an average height of 1.38cm ($SD = .92$). The effect of sodium chloride on height was significant, $F(3, 64) = 8.77, p < .01$ (one-tailed). A significant difference in height at alpha level .05 was identified between the non-saline and strongly saline treatments, ($p < .01$), slightly saline and strongly saline treatments, ($p < .01$), and moderately saline ($p < .01$) and strongly saline treatments.

The 20 plants in the non-saline treatment had an average mass of .09g ($SD = .02$); the 18 plants in the slightly saline treatment had an average mass of .07g ($SD = .02$); the 13 plants in the moderately saline treatment had an average mass of .06g ($SD = .02$); the 17 plants in the strongly

saline treatment had an average mass of .02g ($SD = .02$). The effect of sodium chloride on mass was significant, $F(3, 64) = 47.93, p < .01$ (one-tailed). A significant difference at alpha level .05 in mass was found between the non-saline and moderately saline treatments, ($p < .01$) and non-saline, slightly saline, and moderately saline when compared to strongly saline treatments, ($p < .01$).

The 20 plants in the non-saline treatment had an average root length of 3.58cm ($SD = 1.23$); the 18 plants in the slightly saline treatment had an average root length of 2.10cm ($SD = 1.14$); the 13 plants in the moderately saline treatment had an average root length of 3.23cm ($SD = 2.21$); the 17 plants in the strongly saline treatment had an average root length of .91cm ($SD = .57$). The effect of sodium chloride on root length was significant, $F(3, 64) = 12.74, p < .05$ (two-tailed). There was a significant difference at alpha level .05 in root length between the non-saline and slightly saline treatments, ($p < .05$); non-saline and strongly saline treatments, ($p < .01$); moderately saline and strongly saline treatments, ($p < .01$).

When testing the salinity of soil outside of the Compton Science Center, the first sample was taken from the soil closest to the brick path on the left side. The electrical conductivity meter yielded a reading of 10.52dS/cm, which is strongly saline according to the (NRCS) Soil Salinity Classes for 1:2 soil dilutions. If the soil salinity values in the 1:2 soil dilutions are greater than one, then the soil is considered strongly saline. The first site had very compacted and dry soil, white residue from sodium chloride, and no vegetation. The second sample was taken from the soil next to the main sidewalk, and the soil salinity was 5.83dS/cm, which is also strongly saline. The second site had less compacted soil than the first site but was still compacted, had white residue from sodium chloride, and had small spots of vegetation. The third sample was taken ten meters from the sidewalk in the middle of the grassy area in the quad, and the soil salinity was

.09dS/cm, which is non-saline. The third site had grass covering the whole area, and the soil was moist.

DISCUSSION AND CONCLUSION

The results from the experiment supported the hypothesis that if the sodium chloride concentration in soil increases, then the development and growth of plants will be inhibited. With high sodium chloride levels, the Wisconsin Fast Plants™ experienced a reduction in height, mass, and number of leaves. The strongly saline treatment plants were significantly shorter, lighter, and had significantly fewer leaves than the non-saline, slightly saline, and moderately saline treatment plants. Also, the strongly saline treatment seeds had a delay in germination. All of the seeds that germinated in the non-saline, slightly saline, and moderately saline treatments, had germinated by Day 4 of testing. In contrast, the strongly saline treatment had seeds continuing to germinate after Day 4. Based on these results, the effects of sodium chloride may not be gradual; rather, there might be a threshold of sodium chloride tolerance between the moderate salinity and the strong salinity at which the plants cannot flourish.

The strongly saline plants' germination was likely delayed because the movement of water from the soil to the seeds was slowed. Seeds need water to germinate, and sodium slows water travel in soil by binding to clay particles, reducing the spaces between them and causing dispersion of essential nutrients. Water flows through spaces in the soil, so if the soil is compacted, then the water will travel slower.

The height, number of leaves, and mass of the strongly saline plant stems were likely affected by the chloride. Chloride was accumulating in the stem of the plant and dehydrating the plants. The dehydration caused the plants to stress and stopped the development of height and the

number of leaves. The mass was lowered by dehydration; without as much water absorbed in the plants, the mass was less. The osmotic stress caused by chloride results in the plant pushing water out of the plants roots to balance ion concentration in the soil causing dehydration to the plant. Osmotic stress prevents nutrient intake, causing reduced height, number of leaves, and mass. The root lengths of the strongly saline plants were shorter, likely because high concentrations of salt particles in the soil damage the tissue of the roots and inhibit growth. The salt particles surrounding the roots cause local dehydration and lead to damage of the root system.

This study provides important information about the impacts of sodium chloride on soil and vegetation. The results showed that plants' growth was stunted by saline soils. This suggests that when sodium chloride is used as a deicer in urban areas, the surrounding vegetation may be negatively affected. Plants are filters for groundwater, absorbing pollutants and keeping them from contaminating drinking water. Plants also provide oxygen that many organisms, including humans, require. Furthermore, vegetation helps to prevent soil erosion. If plants are damaged or killed by sodium chloride, it will be easier for erosion to remove the top layer of soil. Based on the data, sodium chloride is harmful when used as a deicer, suggesting a need for alternative methods of clearing ice and snow from roads.

This experiment had certain limitations. One of these limitations was the amount of time available. There was not enough time to allow the plants to complete their lifecycles, so it could not be determined how salinity in the soil would have affected their reproduction. Another limitation concerns the mass measurements that were recorded for plants. Dry masses could not be measured, because after drying, the plants were too light to weigh. This study was also limited in that only one species of plant was used. Wisconsin Fast Plants™ are not common in

urban areas, so they may not reflect species that are exposed to the highest levels of sodium chloride in nature. A final limitation is that soil samples were collected from a limited number of sites on Frostburg State University campus. These may be very different from soils found in urban environments.

The experiment could have been improved by using bigger quadrants. The quadrants used were small and may have limited the growth of the plant roots. Another improvement could have been using a more sensitive scale that weighs to the thousandths place to find the dry mass of the plants. Finally, the study could have included plants commonly found in urban areas. These plants may have yielded different results because they may have been more adapted to sodium chloride.

This experiment could be followed up with several different similar studies. One such study could examine the effects of sodium chloride on plants at various stages of their lifecycle. Another study could investigate the individual effects of sodium and chloride by exposing some treatments only to sodium and others only to chloride. Additional research might test the effects of sodium chloride in different types of soils, such as those taken from urban areas. Another study could test the effects of alternative deicing compounds on the growth of plants. Such alternatives include magnesium chloride, calcium magnesium, and calcium chloride. If these alternatives showed less of a negative impact on plant growth, it could be concluded that they are environmentally safer deicers than sodium chloride.

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