Short Research Article

Differences in growth rates and germination rates of various commercial deicers on *Kochia prostrata* and *Solidago juncea*

.abstract

Aims: To examine the effects of deicers on a plant *Kochia prostrata andSolidago juncea*.

Study design: All studies were replicated three times, with a minimum of 5 seeds per pot.

Place and Duration of Study: Samples were kept at Saint Xavier University. Plants were grown for 4 weeks before harvest.

Methodology: The soil was a 1:1:2 ratio of perlite, peat moss, and soil mix.The seeds were left to germinate and grow under a lamp and were watered with 125mL of deionized water twice a week, every 2 or 3 days until harvest.

Experiment 1:Upon germination, the salt solutions were used in concentrations of 0mM, 50mM, 100mM, 150mM, and 200mM in 125mL portions to water the plants for one time only.

Experiment 2:Upon germination real world applications of deicers were applied to potsone time only.

Experiment 3: The soil mixture was placed in a total of 26 paper cups (24 salt concentrated & 2 controls). The soil was then saturated with 20mL of each salt solution (0PPM,250 PPM, 1000 PPM, 1250 PPM, 2000 PPM) one time only.

Results:
For experiment 1 the effect of the salt solutions showed a statistically significant difference between all the salts and rock salt ($P<0.01$). For experiment 2 two of the salts were statistically significantly different than the control ($p<0.05$). Experiment 3 showed all greatly affected germination in *S. juncea*. Complete Melt Road salt treated plants had at least 50% germination in the 1500 ppm or less.

Conclusion: The high germination rates may have been because the Complete Melt Road salt is not purely made of salt, but instead is mixed with “fillers” that are cheaper than salt. Next steps are to conduct field tests on efficacy of *K.prostrata* and tolerance of *S. juncea* in the field.

Keywords: Road Salt, Germination, Kochia prostrata, Solidago juncea

1. INTRODUCTION

Salt has many uses in society today, such as food preservatives and water conditioning agents. Another major use for salt is when it is used on highways and roadways in order to lower the freezing temperature of ice and snow that has or will be building up on these roads [1]. This is a huge factor in road and highway safety, but is also a danger to soil and crops. The most common deicers (inorganic salts sodium chloride, calcium chloride and magnesium chloride) [2] all used both in solid and liquid or brine form and their usage has increased exponentially over the decades.

Road deicing can reduce accidents by more than 78%, so we must strike a balance and mitigate the negative environmental and health effects caused by dumping salts on the streets and highways to keep both people and the environment safe. A major example of how rad salts overuse likely contributed to negative health effects of human health is that the higher levels of corrosive chloride in the water supply of Flint Mich. in 2014 lead to the release of lead from water distribution pipes [3]. There are also numerous research studies that highlight that show urban streams with salt concentrations that are more than 20 to 30 times higher than the EPA chronic chloride threshold of 230 milligrams per liter [4].

Salt can not only dry out soil, rendering them useless to grow crops, but can also damage the plant itself. High levels of salt, specifically Sodium Chloride (NaCl) can cause an inhibition of growth and development and a reduction in photosynthesis, respiration, and protein synthesis [5]. Prolonged use of de-icing salts has a detrimental impact on the environment, most of all on roadside soils and vegetation [6,7,8]. Abundant evidence demonstrates that elevated concentrations of NaCl ions in the soil solution both directly and indirectly alter plant growth and affect the health status of roadside trees [9,10]. Though plants perceive and respond to salt-induced stress by quickly altering gene expressions in parallel with biochemical and physiological changes [11], prolonged exposure to salts weakens their defense mechanisms. Consequently, Na^+ and Cl^- excessively accumulated in leaf tissue cause direct toxicity through disturbances of metabolic processes and ionic steady state at the cellular level [12,13,14]. Moreover, plant injury can be intensified by salt-induced water stress, producing disruption in normal water and nutrient uptake [15]. The intensity of the disruption in the basic nutrient uptake and plant growth is also species-dependent [16].

This study was divided into three projects to examine the effects of deicers on both nonnative and native plant species. The two species we were interested in were *Kochia prostrata* and*Solidago juncea*. *K.prostrata*is a perennial semi-evergreen subshrub that has been developed as a forage and erosion control plant in the mountainous regions of the western United States, such as Utah, Arizona, Nevada, Oregon, New Mexico, and Wyoming [16]. The shrub is non-invasive, fire-resistant, and has an excellent capacity to choke out invasive exotic weeds [17]. Because these arid and semi-arid regions contain soil and water that have a higher quantity of salt in them, it should be common to have halophytic plants planted in these areas. These plants are excellent to forage land because they can adapt to the saline conditions of the arid or semi-arid regions of the United States [5]. Since *K.prostrata*can forage land and exist in saline conditions, we were interested in two things. The first is to examine the effects that fourstandardized de-icing salts would have on the seedling germination of *K.prostrata*. These salts were regular salt (NaCl), Prestone Driveway Heat (Calcium Chloride), Morton Rock Salt (Sodium Chloride), and Morton Action Blend (CaCl and NaCl). This is very important in determining if *Kochia prostrata* can be used as a barrier against de-icing salt so grass and other plants will not get damaged because of salt runoff. The second experiment is to determine the 'real world 'application rates of each of these deicers and then apply these to *K. prostrata* and determine if we have the same results as with the standardized applications.

Solidago juncea is an herbaceous perennial plant with a life span of over two years [18]. It is mostly found in the Northern-east and Northern-central parts of the United States. *S. juncea*, known as Early Goldenrod, is extensively distributed throughout Illinois [18]. The typical blooming season for *S. juncea* is from July-September. It is mostly found in sand prairies, gravel prairies, oak savannas, sunny waste areas, and road sides Of Illinois. *S. juncea* is the earliest goldenrod to bloom in these habitats in Illinois. They attract a variety of insects such as, long-tongued and short-tongued bees, wasps, flies, butterflies, moths, and beetles. It is also a feeding ground to the caterpillars of many moths and a hiding place for the moths themselves. For these reasons we were interested in the effects of the deicers on a native species. The third experiment for this study was done using four different types of salts: Sodium Chloride, Calcium Chloride, Magnesium Chloride, and Complete Melt Road salt to examine the effects of these salts on the germination rates of a native species versus a species that is known to be salt tolerant. Six different salt concentrations of each salt type were used to water the *Solidago*.

Objectives
The objectives of our study were to determine (1) determine effects of various salts (NaCl,CaCl, MgCl) on *K. prostrata*through brine application, (2) determine the effects of various salts on *K. prostrata* through "real" world

applications, (3) determine the effects of various salts on *S. juncea* , (4) to what extent the variation in severity of salts effect wet/dry weight of plants.

2. MATERIAL AND METHODS

Experiment 1 - *Kochia prostrata*

Kochia prostrata seeds were pre-soaked, and 5 seeds were placed into each individual pot. Paper towel was placed at the bottom of every pot in order to retain more water, and potting mix was filled to an inch below the rim. *Kochia prostrata* seeds were kept in the freezer prior to use, and were distributed to each pot, with five seeds being planted on the surface of the soil, and then lightly sprinkled with more soil to cover the seeds. The seeds were left to germinate and grow under a lamp four 4500K cool white fluorescent bulbs run 24hrs a day, with Humidity >50% & temperature 68-85 degrees F and were watered with 150mL of deionized water twice a week, every 2 or 3 days.

After the seeds grew and every pot had sprouted at least one plant, the salt solutions of Sodium Chloride (NaCl), Aluminum Chloride (AlCl), and Potassium Chloride (KCl) were used in concentrations of 0mM, 50mM, 100mM, 150mM, and 200mM in 125mL portions to water the plants for one time only. After the application of the salt solutions to the plants, each additional watering was with 125mL of deionized water, twice a week, for four more weeks, this experiment was replicated three times.

When the four weeks were completed, the plants were harvested, lightly rinsed, and weighed on a scale in grams for a wet weight, measured in centimeters with a ruler for a length, then left on a paper towel to dry out for three days and then measured again for a dry weight. This was for calculating how much water the plant was able to absorb during its growth.

Experiment 2 - *Kochia prostrata*

Miracle-Gro mix that was pre-soaked in de-ionized water was used in 4 pots. Paper towel was placed at the bottom of every pot in order to retain more water, and the potting mix was filled to an inch below the rim. *Kochia prostrata* seeds were kept in the freezer prior to use, and were distributed to each pot, with ten seeds being planted on the surface of the soil, and then lightly sprinkled with more soil to cover the seeds. The seeds were left to germinate and grow under a lampfour 4500K coolwhite fluorescent bulbs run 24hrs a day, with Humidity >50% &temperature 68-85 degrees Fand were watered with 150mL of deionized water twice a week, every 2 or 3 days.

After the seeds grew and every pot had sprouted at least 5 plants, the de-icing salts were measured out using "real world" application. This included scattering the salts on poster board, just as one would scatter salt on ice during the winter. This was done with all four salts; Morton Action Blend, Prestone Driveway Heat, NaCl, Rock Salt. An average amount in grams was taken, (5 g; 7.6 g; 4.8g; and 10.6 g respectively) and then scaled down for use with the pots. The salt was dissolved in 150mL of de-ionized water, and then applied to the plants for one time only. After the application of the salt solutions to the plants, each additional watering was with 150mL of deionized water, twice a week, for two more weeks and this experiment was replicated three times

When the four weeks were completed, the plants were harvested, lightly rinsed, and weighed on a scale in grams for a wet weight, measured in centimeters with a ruler for a length, then left on a paper towel to dry out for three days and then measured again for a dry weight. This was for calculating how much water the plant was able to absorb during its growth.

Experiment 3 - *Solidago juncea*

The *S. juncea* seeds were initially prepared by soaking them in 10mL of salt concentrated deionized water. They were wrapped in a soaked paper towels and placed in a plastic bag, then refrigerated for 48 hours before put to use. There was a total of 24 bags of salt-soaked seeds. All salts had concentrations of 0, 250, 500, 1000, 1250, 1500, and 2000 ppm.
The soil was then prepared using a 1:1:2 ratio of perlite, peat moss, and soil mix. The soil mixture was placed in a total of 26 paper cups (24 salt concentrated & 2 controls). Each cup was then labeled indicating the salt type and concentration. The soil was then saturated with 20mL of each salt solution. 24 hours after saturating the soil, the seeds were planted Thirty seeds per salt treatment were used. They were buried approximately 1 cm deep, and fully covered by the soil. Prior to germination, the plant trays were covered using saran wrap to lock in the humidity, stimulate germination and prevent leaching. The plants were monitored daily and watered on average of 3 times a week or as needed. The *S. juncea* was watered twice using the salt concentrated solutions over a span of two weeks. They were monitored 3 times a week for germination, temperature, and humidity.The seeds were left to germinate and grow under a lamp four 4500K cool white fluorescent bulbs run 24hrs a day, with Humidity >50% & temperature 68-85 degrees F and were watered with 150mL of deionized water twice a week, every 2 or 3 days.

3. RESULTS AND DISCUSSION

Experiment 1 – *Kochia prostrata*

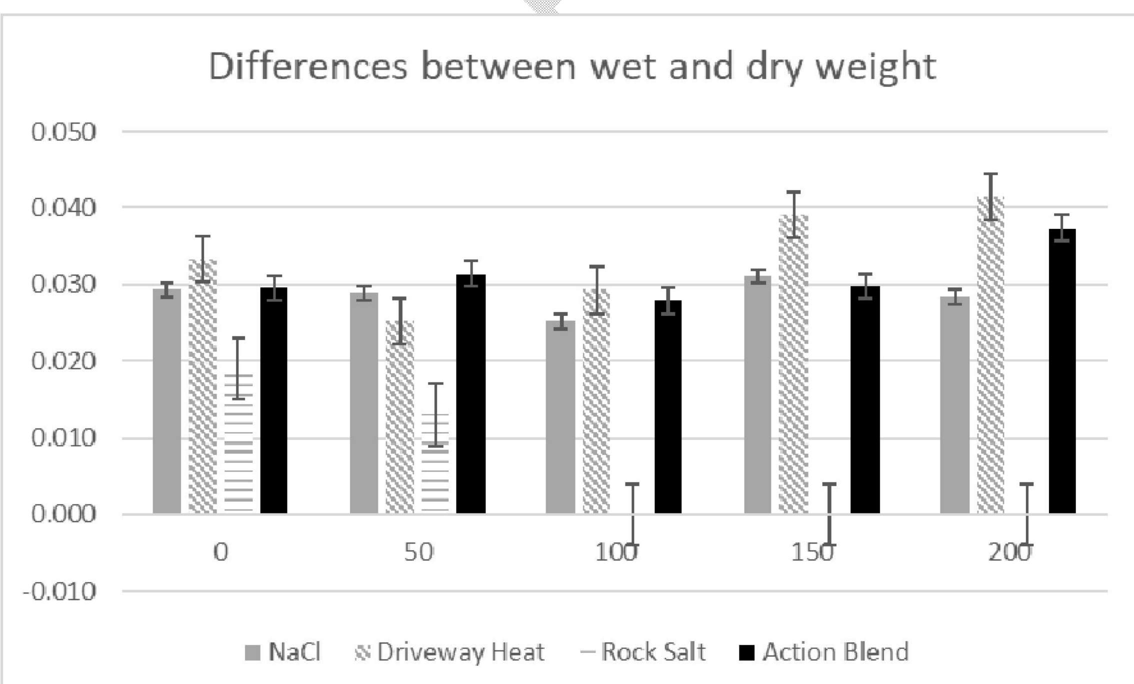
The effect of the salt solutions showed a statistically significant difference between all of the salts compared with rock salt ($P<0.01$).For NaCl weights decreased at 100 mM then increased to not statistically significantly above the control weight. Similar patterns were seen with Driveway Heat ($P=0.002$) and Action Blend ($P = 0.001$). Rock Salt is the only one where all plants died above 150 mM.

Table 1. Average differences in wet and dry weight as a result of various salts and concentrations on plant length (0, 50, 100, 150, 200mM) on plant growth of *Kochia prostrata*

Wet and Dry Weights of Kochia prostrata at Various Salt Concentrations										
Salt Blends	**0 mM**		**50 mM**		**100 mM**		**150 mM**		**200 mM**	
	Wet Weight	**Dry Weight**	**Wet Weight**	**Dry Weight**	**Wet Weight**	**Dry Weight**	**Wet Weight**	**Dry Weight**	**Wet Weight**	**Dry Weight**
NaCl	0.073 g ± 0.03	0.044 g ± 0.02	0.072 g ±0.01	0.043 g ±0.01	0.063 g ± 0.03	0.038 g ± 0.05	0.078 g ± 0.02	0.047 g ± 0.04	0.071 g ± 0.01	0.043 g ± 0.02
Driveway Heat	0.068 g ± 0.02	0.035 g ± 0.01	0.063 g ±0.03	0.038 g ±0.04	0.073 g ± 0.04	0.047 g ± 0.03	0.078 g ± 0.01	0.047 g ± 0.01	0.079 g ± 0.04	0.043 g ± 0.04
Rock Salt	0.048 g ±0.06	0.029 g ±0.01	00.33 g ±0.03	0020 g ±0.03	0.040 g ± 0.05	0.039 g ± 0.05				
Action Blend	0.074 g ±0.01	0.044 g ±0.06	0.079 g ±0.03	0.047 g ±0.03	0.070 g ± 0.03	0.045 g ± 0.03	0.075 g ± 0.02	0.045 g ± 0.02	0.077 g ± 0.03	0.040 g ± 0.03

Mean ± S.E.M = Mean values ± Standard error of means of three experiments

Fig. 1.Difference between wet and dry weight as a result of various salts and concentrations on plant length (0, 50, 100, 150, 200mM) on plant growth of *Kochia prostrata*



Experiment 2 – *Kochia prostrata – Real world application*

Two of the salts were statistically significantly different than the control ($p<0.05$); Rock Salt ($P=<-0.01$) and Driveway Heat ($P = 0.002$) when it came to differences between Wet and Dry weight. All four of the blends have significant differences in plant length.There was a 11.58 cm difference between the control and Rock Salt andall but two plants per trial on average died. There was an average 1.54 cm difference between the control plants and the NaCl plants ($P=1.60E-05$). There was an average 1.12 cm difference between the control plants and the Prestone Driveway Heat ($P =7.10E-04$) plants. Finally, there was a 1.02 cm difference between the control plants and Action Blend ($P = 1.04E-02$).

Table 2. Average differences in wet and dry weight and plant heights a result of various salts and concentrations on plant length in real world application rates on plant growth of *Kochia prostrata*

Wet and Dry Weights and Length Differences of Kochia prostrata at Various Salt Concentrations			
	Wet Weight	**Dry Weight**	**Length**
Control	0.08 g ± 0.04	0.038 ±0.01	18.5 cm ± 1.1
NaCl	0.073 g ± 0.03	0.043 g ± 0.02	16.96 cm±0.5
Driveway Heat	0.065 g ± 0.04	0.037 g ± 0.01	17.38 cm±0.25
Rock Salt	0.015g±0.06	0.021 g ±0.01	6.92 cm±0.03
Action Blend	0.073 g ±0.01	0.044 g ±0.06	17.48 cm ±2

Experiment 3 - Solidago juncea

Magnesium Chloride, Calcium Chloride, and Sodium Chloride all greatly affected germination in *S. juncea*. Unexpectedly, the Complete Melt road salt treated plants had at least 50% germination in the 1500 ppm or less treated plants. *S. juncea* treated with 500 and 1250 ppm had a germination of 100%.

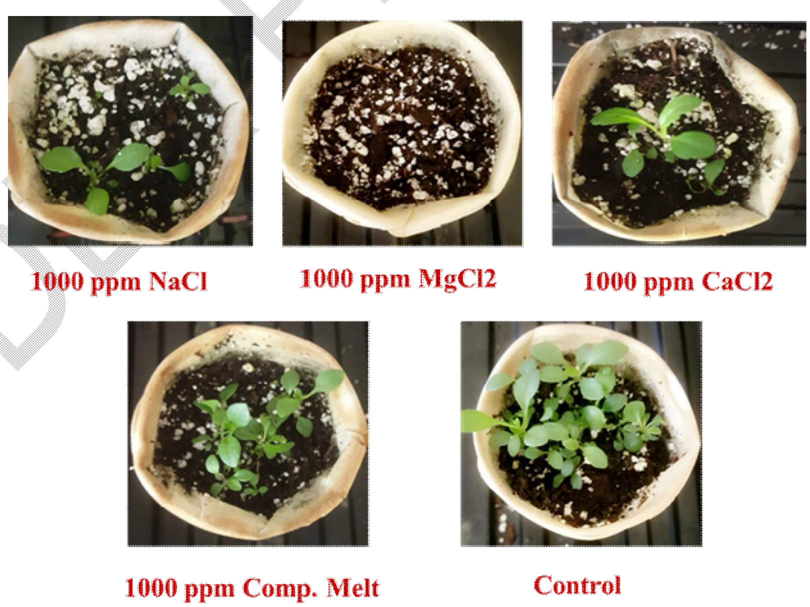
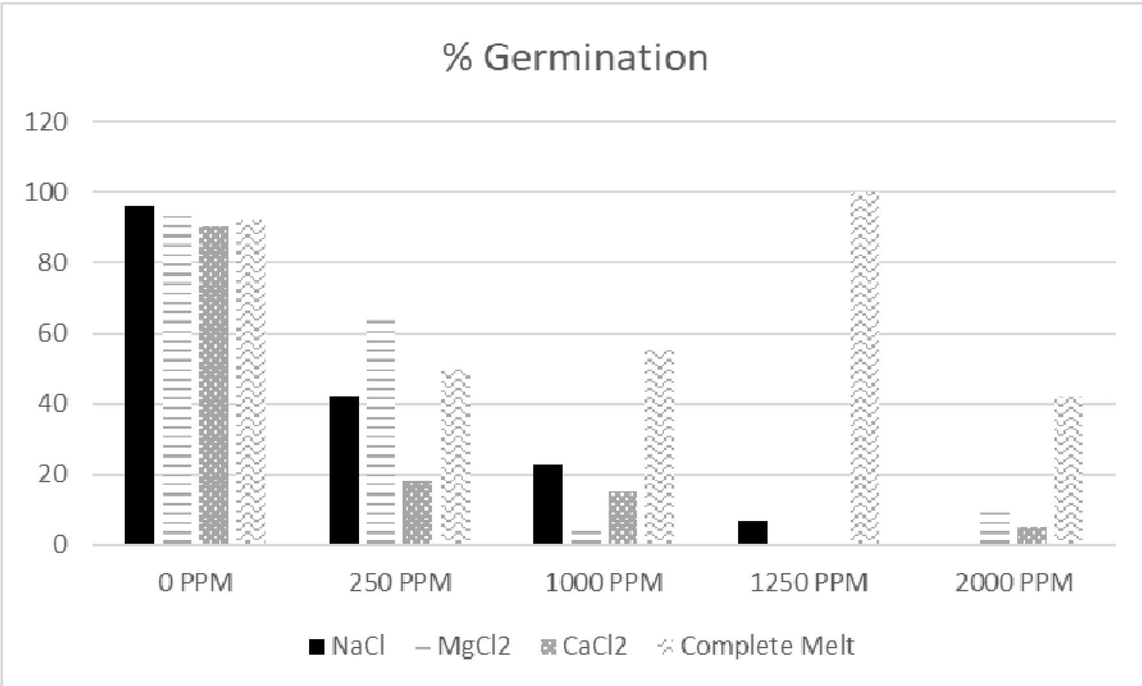


Fig.2.Difference in germination rate of *Solidago juncea* at 1000 ppm of NaCl, $MgCl_2$, $CaCl_2$, and Complete Melt.

Fig.3.Percent germination rates of *Solidago juncea* at various concentrations of salt.



4. CONCLUSION

While we have utilized road salts to combat icy roads and deice planes for scores of years now, we are coming to understand the environmental impacts that we are having on the ecosystem. These substances are riddled with compounds that are plagued by growing concerns over their effects on metals, destructive impact on concrete and asphalt and toxicity to the aquatic environment and other resources.

The results from our *K.prostrata*work have answered some questions but have led to many others. We have answered the question of whether this forage crop can withstand some of the deicers; and found some much better than others which are utilized better than others, as has been demonstrated by our work here. Our next goals are multifaceted for this species. We would like to determine:

1. Can this crop survive in Illinois winters?
2. If so, can it thrive well enough to withstand stressors induced by salt spreading in the winter?
3. What impact does this crop have to the surrounding environment with regards to bioremediation of salts?

While all of the salts did affect the germination rates of *S. juncea*, Complete Melt road salt treated plants had at least 50% germination in the 1500 ppm or less treated plants*. S. juncea* treated 1250 ppm had a germination of 100%. This may have been because the Complete Melt Road salt is not purely made of salt, but instead is mixed with “fillers” that are cheaper than salt. Unfortunately, these “fillers” are not listed on deicer packages because of patent issues. These “fillers” are most likely not plant damaging. As shown in the results, a slight consistency was apparent in the relationship between an increase in salt concentration and a decrease in germination. This leads to the question of which natural alternatives would be as effective in managing salt, but still providing safe alternatives for the environment? Our next goals for the native species are to:

1. Rerun the experiment with some more ‘natural’ deicers to determine their efficacy on germination and growth rate.
2. Pretreat the soil and then determine the germination rates.

Up to this point in our experiment, we have only studied the effects of salt concentration on the germination of *S. juncea*. We will be conducting at least one replicate experiment to ensure that our results are precise. We will also conduct an ion chromatography on each of our samples. This will help us determine the number of ions that are absorbed by the *S. juncea*. Histological examinations will also be run on the root tips and leaves of our samples. This will allow us to view the effects of deicers on the actual cells of the *S. juncea* and will allow us to compare their appearance based on the type of salt that the plant was treated with. We are also currently studying the effects of deicers on the growth of the *S. juncea* by measuring stem and leaf lengths.

REFERENCES

1. National Academy of Sciences. Guidelines for the Selection of Snow and Ice Control Materials Mitigate Environmental Impacts. National Cooperative Highway Research Program, NCHRP Report 577. 2007;16:4. Accessed 29 May 2023. Available: http://www.nap.edu/catalog/23178/guidelines-for-the-selection-of-snow-and-ice-control-materials-to-mitigate-environmenta-impacts.

2. Sajid HJ, Kiran R, Qi, X, Bajwa DS, Battocchi, D. Employing corn derived products to reduce the corrosivity of pavement deicing materials. Construction and Building Materials. 2020; 263:10 https://doi.org/10.1016/j.conbuildmat.2020.120662

3. HintzWD, Fay L, Relyea RA. Road salts, human safety, and the rising salinity of our fresh waters. Frontiers in Ecology and the Environment, 2021; DOI: 10.1002/fee.2433

4. University of Toledo. "Study shows critical need to reduce use of road salt in winter, suggests best practices." ScienceDaily. ScienceDaily Accessed 9 December 2021. www.sciencedaily.com/releases/2021/12/211209124519.htm

5. Karimi G, Ghorbanli M, Heidari H, Khavari Nejad RA, and Assareh MH. "The Effects of NaCl on Growth, Water Relations, Osmolytes and Ion Content in Kochia Prostrata." Biologia Plantarum 2005: 301-304.

6. Viskari, EL &Kärenlampi, L. Roadside scots pine as an indicator of deicing salt use—A comparative study from two consecutive winters. Water Air Soil Pollut. 2000. 122, 405–419.

7. Pajak, M, Krzaklewski W, Duda K & Gruba P. Spatial and temporal variation in soil salinity as a result of chemical de-icing of road in Krakow, Poland. Frasenius Environ. Bull. 2015. 24(10A), 3363–3370.

8.Goodrich B & Jacobi W. Foliar damage, ion content, and mortality rate of five common roadside tree species treated with soil applications of Magnesium Chloride. Water Air Soil Pollut. 2012. 223(2), 847–862.

9. Yi Z, ShuoL, Ying L, Hailiang Z, Leiping H, Shi Y, and Golam J A. Effects of exogenous spermidine and elevated CO_2 on physiological and biochemical changes in tomato plants under iso-osmotic salt stress. J. Plant Growth Regul. 2018. 37, 1222–1234.

10. Snieškienė V, BalažentienėL&Stankevičienė A. Urban salt contamination impact on tree health and the prevalence of fungi agent in cities of the central Lithuania. Urban For. Urban Green. 2016. 19, 13–19.

11. Chaves MM, Flexas J & Pinheiro C. Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. Ann. Bot. 2009. 103, 551–560.

12. Ashraf, M. The effect of NaCl on water relations, chlorophyll, and protein and proline contents of two cultivars of blackgram (Vignamungo L.). Plant Soil 1989. 119, 205–210.

13. Hasegawa P, Bressan R, Zhu JK & Bohnert H. Plant cellular and molecular responses to high salinity. Annu. Rev. Plant Physiol. Plant Mol. Biol. 2000.51, 463–499.

14. Parida AK & Das AB. Salt tolerance and salinity effects on plants: A review. Ecotoxicol. Environ. Saf.2005.60, 324–349.

15. Munns, R. Comparative physiology of salt and water stress. Plant Cell Environ. 2002. 25, 239–250.

16. Harrison RA, Chatterton NJ, Waldron BL, Davenport BW, Palazzo AJ, Horton WH, and Asay KH. Forage Kochia Its Compatibility andPotential Aggressiveness onIntermountain Rangelands.Research Report 162Utah Agricultural Experiment StationUtah State University. Available: https://www.ars.usda.gov/ARSUserFiles/20801000/pdfs/Forage_Kochia.pdf

17. Marosz, A. & Nowak, JS. Effect of salinity stress on growth and macroelements uptake of four tree species. Dendrobiology2008. 59, 23–29.

18. "What is Immigrant Forage Kochia?" KochiaSeed.Com. Accessed 28 Apr. 2008 Available: http://kochiaseed.com/whatisit.html

19. Lady Bird Johnson Wildflower Center. Accessed 5 March 2021. Available: https://www.wildflower.org/plants/result.php?id_plant=SOJU