Final Abstract

Final Report Approved on December 8, 2025

M.L. 2022 Project Abstract

For the Period Ending June 30, 2025

Project Title: Phytoremediation for Extracting Deicing Salt

Project Manager: Bo Hu

Affiliation: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Website: https://cfans.umn.edu/

Funding Source:

Fiscal Year:

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 08g

Appropriation Amount: $451,000

Amount Spent: $451,000

Amount Remaining: -

Sound bite of Project Outcomes and Results

This project demonstrated that salt-tolerant plants such as sugar beet and sunflower can remove road salts from contaminated soils and waters and retain in their biomass. Field trials confirmed their effectiveness for large-scale roadside application, offering a potential sustainable solution to protect Minnesota's water quality, soil health, and surrounding ecosystems.

Overall Project Outcome and Results

Minnesota's lakes, wetlands, and roadside soils are increasingly threatened by salt pollution from winter deicing and agricultural runoff. High salt levels can damage vegetation, degrade soil, and contaminate groundwater and surface water. This project explored natural, plant-based methods to reduce salt levels in the environment using species that can absorb and store salts through their roots—a process called phytoremediation. Our team evaluated several salt-tolerant plants and identified two particularly effective species: sugar beet (Beta vulgaris) and common sunflower (Helianthus annuus). Greenhouse studies showed that sugar beet plants accumulated up to three times more sodium and chloride than other tested species, while sunflowers transported chloride efficiently to their above-ground tissues. These traits make sugar beet ideal for long-term salt reduction and sunflower useful for short-term or seasonal salt

cleanup. We then tested these species in field settings, including roadside sites and a saline pond. Field trials confirmed that both sugar beet and sunflower grew successfully in local conditions and removed substantial amounts of salt from soil. Monthly monitoring at four highway sites showed that soil salt levels changed with precipitation, with some sites having much higher contamination risks. Harvesting studies demonstrated that sunflowers could effectively remove salt within a three-month growing period, providing practical guidance for roadside management. Combining these salt-absorbing plants with existing Minnesota Department of Transportation (MnDOT) vegetation further improved salt removal, although replanting may be needed periodically to maintain effectiveness. Additionally, we found that the microbe Pseudomonas fluorescens could enhance sunflower growth under salinity, further increasing its overall salt uptake. Overall, this project demonstrates that using common, fast-growing plants for salt cleanup is both feasible and environmentally beneficial. These findings offer Minnesota agencies science-based strategies to manage roadside and agricultural salinity, protect soil and water health, and sustain resilient landscapes for future generations.

Project Results Use and Dissemination

Our project results were disseminated through multiple academic and outreach activities. Findings were presented at the 2023 and 2024 Bioproducts Symposia and the 2024 and 2025 CFANS Symposia, showcasing advances from hydroponic salt-removal studies to field-scale floating island applications. Results were also shared at the 2025 Climate Change Conference and 2025 Annual ASABE conference highlighting nature-based desalination technologies. Additionally, team members delivered a guest lecture in BBE 4607 – Industrial Biotechnology and the Environment (Spring 2024), introducing students to phytoremediation of road salts. These dissemination efforts expanded awareness of plant-based salt mitigation strategies among researchers, students, and environmental professionals across Minnesota.

Environment and Natural Resources Trust Fund

M.L. 2022 Approved Final Report

General Information

Date: December 22, 2025

ID Number: 2022-214

Staff Lead: Lisa Bigaouette

Project Title: Phytoremediation for Extracting Deicing Salt

Project Budget: $451,000

Project Manager Information

Name: Bo Hu

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Project Reporting

Final Report Approved: December 8, 2025

Reporting Status: Project Completed

Date of Last Action: December 8, 2025

Project Completion: June 30, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 08g

Appropriation Language: $451,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to protect lands and waters from contamination by collaborating with the Department of Transportation to develop methods for using native plants to remediate roadside deicing salt.

Appropriation End Date: June 30, 2025

Narrative

Project Summary: We propose to develop application methods to apply native plants that can adsorb salts to be planted on the roadside to address the environmental concerns over deicing road salts.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The icy conditions of Minnesotan winters require aggressive applications of road salts to melt the snow on sidewalks and roads. The continued contamination of salt can negatively affect the health of surrounding ecosystem. It is easy to leach into lakes, rivers, and groundwater, causing significantly increased salinity. Many lakes (for instance, Loring pond and Diamond lake) around the Twin Cities have already been reported to have chloride concentrations consistently surpassing the environmental standard of 230 mg/L. High salt conditions can also negatively affect both plant growth and soil structure. Contaminated soil can affect up to 10 m off of a roadside increasing soil density and alkalinity causing problems with erosion and vegetation. Phytoremediation is an emerging method to extract salts from the soil by utilizing the growth of certain plants and then remove salts by harvesting the plant biomass. These plants are typically halophytes, which excrete salt ions through specialized leaf glands. The harvested halophytic plant biomass may have some industrial applications, for instance, serving as animal feed or energy source. Phytoremediation has numerous advantages over the conventional techniques for salt remediation, such as removing the contaminated soil to landfill while replacing it with clean soil, leaching, chemical amendments.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

LCCMR funded our research project (July 2019-June 2022) to study possible native plants that can be used for phytoremediation of road salts. With this support, we have developed an inventory list of possible native halophytes, are testing several potential top roadside plant species in the greenhouse study, and are planning to grow these plants outside on the roadside in collaboration with MnDOT. The outcome of the current project provides a solid foundation for this approach and we are requesting a continuation of the project support to further develop application methods to be use for roadside for salt remediation. The continuation project will first study how these halophytes will survive and interact with other roadside vegetation; we will also study how these interactions will affect the overall road removal efficiency. We will then apply ecological engineering principles to develop different application methods, for instance rain gardens for roadside soil and floating islands for water bodies, for use as remediation solutions. Finally, as a way to optimize the effectiveness of salt uptake by plants, we will explore how soil microbial communities can help plants assimilate salts with the goal of developing biofertilization approaches for salt remediation on Minnesota roadsides.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

This project is based on our current research and will provide a comprehensive methodology to apply native halophytes to the roadside environment for salt remediation. The specific outcomes of the project include three aspects to the road-salt phytoremediation: 1, information on how to mix the halophytes with current roadside plants and how they adapt to the local environment; 2, what ecological design methods are available to apply halophytes for roadside salt remediation; 3, a new microbial biofertilizer to increase and maintain the plant capability for salt tolerance and assimilation.

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Field study of halophyte mixed with roadside plants on different soils

Activity Budget: $147,000

Activity Description:
We are currently working with MNDOT to move some of our best plant species to the field testing stage in summer 2021. In the next step, we want to study different establishment and harvest methods to reach the optimized salt removal from roadside soil and water. We will plant single species, mixtures of halophytes, and mixtures of halophytes with non-halophytes at MnROAD Albertville roadside or UMN Saint Paul testing sites, representing at least 2 different soil types. We want to understand how competitive halophytes will be with other plant species and what harvest frequency is needed so that they will be able to remove salt in different growth environments. The selected specimen from the lab tests will be planted in the spring on this pilot testing lot and monitored for the entire growing season. We will take plant and soil samples from field sites, measure the plant biomass, nitrogen (TN), phosphorus (TP and PO4-P), and the salt concentration in the shoots, roots, and soil at our lab. We will use this information to develop an implementation plan for how this species will be added into current regional seed mixtures for plantation diversity and how to maintain their growth.

Activity Milestones:

Description	Approximate Completion Date
Field study of halophytes growing with native roadside plants	June 30, 2023
Harvesting methods for halophytes and native roadside plants	June 30, 2023
Adaptation of halophytes to different types of roadside soil	June 30, 2023
Plant biomass, nitrogen, phosphorus, and salt concentration measurements in the lab	September 30, 2023

Activity 2: Application methods for roadside soil and waterbody

Activity Budget: $150,000

Activity Description:
We will use ecological design principles to develop application strategies, for instance, rain garden design for road side soil and floating islands placed in storm water ponds. Besides salt removal, we will investigate the nutrient removal efficiencies. For example, will nitrification (and loss of N to the atmosphere) be accounted for in the nutrient removal efficiencies, or will it be assumed that the plant used this portion of the N? Depending on the locations where we want to work on our field trial, we may either build a rain garden or wetland that halophytes will be planted in order to calculate the salt remediation as well as nutrient removal. This design is totally determined by the local hydrology conditions and we will consider the soil structure properties in the experiments. Designs will be modeled before construction to optimize the design efficiency and to provide modeling guidance for practitioners. The plan will also consider effects of this species on the roadside stabilization and safety, a better outcome for NPDES permit compliance for obtaining a uniform, perennial cover, changes to standard specification for construction activities, structural root system enhancement that increase the shear resistance for reducing soil slides, flood overtopping stability, etc.

Activity Milestones:

Description	Approximate Completion Date
Ecological designs of roadside soil application	January 31, 2024
Aquaponics study for halophytic plants	March 31, 2024
Floating island designs for nearby waterbody	June 30, 2024

Determining field sites, building and installing application strategies, and monitoring these field applications	September 30, 2024

Activity 3: Fertilization microbes to enable plants for higher salt assimilation

Activity Budget: $154,000

Activity Description:

This activity will focus on a new perspective to fertilize or even enable current roadside plants for better salt tolerance and assimilation. Several microorganisms, including plant growth-promoting bacteria and arbuscular mycorrhizal fungi, have been shown to alleviate salt stress in various plant species. However, in nature, organisms exist in complex communities, and rhizosphere microbes may act synergistically to alleviate abiotic stresses. Our goal of this step is to elucidate the role of the rhizosphere microbial community in conferring salt tolerance to roadside plants and develop fertilization approaches to enable roadside plants for better salt assimilation. The research will include breeding a salt-tolerance microbiome through multiple generations of artificial selection, Identifying key microbial taxa and genes involved in microbially-mediated salt tolerance, and testing synthetic communities of microorganisms for their ability to assimilate salt into roadside plants. Microbiome engineering has been used to breed microbiomes associated with specific phenotypic traits in Arabidopsis and recently to confer salt tolerance in the model grass, Brachypodium. We expect that this approach will also work to breed a rhizosphere microbial community in the lab that increases salt assimilation to many roadside plants such as turf and we wil confirm our results with greenhouse growth study.

Activity Milestones:

Description	Approximate Completion Date
Study of selected microbial community to tolerate high salt environment and possible assimilate into cells	January 31, 2025
Assemble multiple microbes as biofertilizer for plant revitalization and halophytic maintenance in the lab	May 31, 2025
Application of microbial biofertilizer for roadside halophytes and test in the greenhouse growth study	June 30, 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
John A. Chapman	University of Minnesota	Co-PI	Yes
Eric Watkins	University of Minnesota	Co-PI	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
We will publish two to three peer-reviewed manuscripts in the related journals to disseminate our results to the general public. We will also use the university extension website www.extension.umn.edu as well as PI's academic website http://bohu.cfans.umn.edu/ for dissemination of the research. We will also explore the possibilities to add this module to the UMN Summer Camp program or CFANS booth at MN State Fair to showcase the general public about our mission toward the overall environmental protection.

The primary target to disseminate our research results will be the scientific community, MNDOT as well as local community concerned with the road salt pollution. Information obtained from the plant cultivation experiments will be directly applied to establish possible implementations and business models in order to develop a sustainable solution for the road salt remediation. The research results will be fully disseminated to the public and we are not anticipating any patents or revenues from the project. However, any possible royalty, copyright, patent, and sales of products and assets resulting from this project will be subject to revenue sharing requirements with ENRTF according to Minnesota Statutes, section 116P.10.

Environment and Natural Resources Trust Fund will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENTRF Acknowledgment Guidelines.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
The project will have a broad impact on both academia and industry. The results will provide methods to apply these native plants to mobilize and excrete salt from the roadside soil and water environment. The possible applications will contribute to the sustainable developments in road salt management and agricultural practices, and alleviate the deteriorating conditions related to road salt application and improper irrigation. With the completion of this project, we will seek continuation funds from MnDOT for the specific implementation of this methods at different locations.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Next Generation Large-Scale Septic Tank Systems	M.L. 2014, Chp. 226, Sec. 2, Subd. 08g	$258,000
Biofilm Technology for Water Nutrient Removal	M.L. 2015, Chp. 76, Sec. 2, Subd. 04b	$281,000
Extracting Deicing Salt from Roadside Soils with Plants	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04i	$360,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount	$ Amount Spent	$ Amount Remaining
Personnel										
PI/Bo Hu		Lead project, research, supervise, analyze - summer salary only			36.5%	0.27		$41,774	-	-
One research professional		research - new hire			36.5%	3		$189,111	-	-
63.4% graduate student research assistantship		research			45%	0.96		$95,674	-	-
One - two undergraduate students or temporary student workers		research assistance (academic year only - approx 430 hours per year)			0%	0.6		$15,302	-	-
Co-PI/John Chapman		Co-lead the project, research, supervise, analyze - summer salary only			36.5%	0.18		$25,065	-	-
Co-PI/Eric Watkin		Co-lead the project, research, supervise, analyze - summer salary only			36.5%	0.18		$25,065	-	-
							Sub Total	**$391,991**	**$391,991**	**-**
Contracts and Services										
University of Minnesota	Internal services or fees (uncommon)	The lab services include the greenhouse space rental, which is $216.18 per month.				0		$7,356	$7,356	-
University of Minnesota	Internal services or fees (uncommon)	Sample analysis such as soil testing at UMN Soil Testing Center or UMGC for DNA sequencing				0		$4,334	$4,334	-
							Sub Total	**$11,690**	**$11,690**	**-**
Equipment, Tools, and Supplies										

	Tools and Supplies	lab supplies include plant seeds, chemicals to make nutrient solutions, chemicals to run HPLC and IC for nutrient analysis, chemicals for molecular operations like gene extraction etc. The lab supplies also include some materials for our daily lab and greenhouse operations, for instance, gloves, weight dishes, filter paper, etc. No large equipment over $5000 is requested	The plant seeds and nutrient solutions are used for greenhouse study and field study.					$40,444	$40,444	-
	Capital Equipment	One pump for ion chromatography	Purchase of an IC pump to replace the one broken for sodium chloride analysis	X				$5,880	$5,880	-
							Sub Total	**$46,324**	**$46,324**	**-**
Capital Expenditures										
							Sub Total	**-**	**-**	**-**
Acquisitions and Stewardship										
							Sub Total	**-**	**-**	**-**
Travel In Minnesota										
	Miles/ Meals/ Lodging	This will only cover the department vehicle use to travel to our field site. We are planning around 15 trips each year to go to the field. Each trip is around 86 miles with three students. The mileage is $0.56/mile with inflation adjustment each year.	mileage to sites for planting and samplings					$995	$995	-
							Sub Total	**$995**	**$995**	**-**
Travel Outside Minnesota										
							Sub Total	**-**	**-**	**-**
Printing and Publication										

							Sub Total	**-**	**-**	**-**
Other Expenses										
							Sub Total	**-**	**-**	**-**
							Grand Total	**$451,000**	**$451,000**	**-**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Equipment, Tools, and Supplies		One pump for ion chromatography	This fund will be used to replace a broken pump on our current IC system. The IC has been exclusively used for salt analysis **Additional Explanation :** This pump will be installed into our current ion chromatography as capital equipment, and the system will continue being used for LCCMR projects for chemical analysis through its useful like.

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount	$ Amount Spent	$ Amount Remaining
State						
In-Kind	UM F&A	Since this project does not charge any indirect cost, therefore University of Minnesota matches the in kind service F&A. The current indirect cost rate is 54% of the direct total project cost	Secured	$225,640	$225,640	-
			State Sub Total	**$225,640**	**$225,640**	**-**
Non-State						
			Non State Sub Total	**-**	**-**	**-**
			Funds Total	**$225,640**	**$225,640**	**-**

Attachments

Required Attachments

Visual Component

File: b660045b-2c6.pdf

Alternate Text for Visual Component

We propose to develop implementation approaches to apply halophytes for road side phytoremediation of de-icing salt...

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
MNDOT original supporting letter	f234f4b7-818.pdf
Recent communication with MnDOT for field testing site	53e0f9e1-d6e.pdf
Approval for re-using the supporting letter	21b8c805-b17.pdf
Institutional Approval to Submit	73bb3404-841.pdf
background check form	d9cb9872-fd9.pdf
Poster presentation at UMN BBE Annual Showcase 2023	40937ec4-2a8.pdf
Poster presentation at CFANS Research Symposium 2024	007a0e3d-2af.pdf
Poster presentation at UMN BBE Annual Showcase 2024	23d8ba05-9ca.pdf
Poster presentation at CFANS Research Symposium 2025	761d5178-f31.pdf
Oral presentation at 2nd Global Summit on Climate Change & Environmental Sustainability, September 18-19, 2025 in Los Angeles, CA	11a10bef-c5b.pdf
(Under review) Assessing Plant-Based Strategies for Phytodesalination of Road Salt-Contaminated Runoff	a48dd1d2-c88.pdf
(In preparation for submission) Potential of Various Beet (Beta vulgaris subsp. vulgaris) Varieties to Remediate Salt Impacted Agricultural Soils	c69cd79f-85d.docx
(In preparation for submission) Evaluation of the Phytoremediation Ability of Common Sunflower and Perennial Sunflowers	0ddd3809-717.docx
(In preparation for submission) Screening Plant Species for Phytoremediation of Road Salt from Contaminated Roadside Soil	1db4b090-dd2.docx
Guest lectures	57e8f483-681.docx

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Budget is adjusted to reflect the approved funding amount, including reducing the graduate student appointment from one full graduate to 0.634 graduate student, and adjusting the lab service fees to pay for the greenhouse rental. I removed the travel stipend and increased the graduate appointment percentage so that it can be reflected as labor instead of travel. Other budget items are also corrected based on the instructions.

I added milestones on both activities 1 and 2 as requested; and also added some description on activity 3 to explain what we want to work with. We have several strains we found from the reference, and we also want to screen several strains to test in the lab and greenhouse study for the biofertilizer concept to increase the salt tolerance and/or assimilation by the plants. So no need to add a specific milestone for microbial community study. Please let me know if

anything else is needed to clarify the proposed work. Thanks a lot for your suggestions

I added the UM F&A and also the acknowledgement statement. Please check and see if anything else is missing. Thanks for your help

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

No

Does the organization have a fiscal agent for this project?

No

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	• Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies	1. request to move $6000 from analytical service to purchase an IC pump. Our ion chromatography is exclusively used to analyze sodium chloride for this project and now we need to replace one broken pump. 2. change the undergraduate student employee description to include temporary student workers. Current description only has undergraduate students, but we are hiring a student who will join the U in the fall semester and can only be hired as temporary	May 24, 2024	Yes	May 24, 2024
2	Amendment Request	• Budget • Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Budget - Non-ENRTF Funds Contributed • Attachments	We request to increase the lab service fee to reflect the rental cost of greenhouse facility. Originally we planned to work on greenhouse study for one and half years, but we actually continued our greenhouse study throughout the entire 3 years with additional space needs because we repeated some studies for three times in order to make sure our results are consistent and repeatable.	September 11, 2025	Yes	September 11, 2025

Status Update Reporting

Final Status Update August 14, 2025

Date Submitted: September 10, 2025

Date Approved: September 11, 2025

Overall Update

The project aimed to develop effective plant-based methods for remediating salt-contaminated water and roadside soils. Through six research activities, including hydroponic, greenhouse, and field experiments, these species were identified as highly effective in phytoremediation. B. vulgaris showed superior salt accumulation, retaining salts even when environmental salinity dropped, making it ideal for long-term salt retention. H. annuus, in contrast, preferentially transported chloride to above-ground tissues and released salts under low-salt conditions, suggesting its suitability for dynamic salt removal. Field trials, including artificial floating islands in saline ponds and roadside planting along highways, confirmed their salt uptake efficiency, mirroring lab results. Additional monitoring across four highway sites revealed site-specific contamination patterns, with H. annuus and native cattails performing well across varying salt levels. Harvesting and integration studies indicated effective NaCl extraction in a practical three-month cycle and improved performance when mixed with existing MnDOT plantings, though replanting may be required for long-term impact. These findings demonstrate the practicality and scalability of using salt-tolerant plants for remediating saline environments caused by road runoff and agricultural salinization.

Activity 1

This step explored plant-based strategies to remediate salt-contaminated water, particularly from road runoff. Six salt-tolerant species were selected using Multi-Criteria Decision Analysis (MCDA), emphasizing salt tolerance, phytoremediation efficiency, seed availability, germination speed, and biomass value. Among them, Helianthus annuus (sunflower) and Beta vulgaris (sugar beet) were identified as the top candidates due to their high salt accumulation and biomass yield. In hydroponic experiments, both species effectively removed Na^+ and Cl^-, with H. annuus showing high shoot biomass and Cl^- transport to above-ground tissues, and B. vulgaris displaying superior root biomass and stable salt accumulation. Harvest timing experiments revealed that extended growth increases salt removal by boosting biomass, not tissue concentration. Nutrient studies showed that Cl^- uptake in sunflower increased with nutrient availability, while sugar beet maintained constant salt levels regardless of nutrients. A salt-release study found H. annuus released about 50% of stored salts when salinity dropped, whereas B. vulgaris retained them, indicating suitability for dynamic and permanent remediation, respectively. These findings underscore species-specific responses and inform tailored application strategies for roadside and waterway salt pollution, emphasizing practical, scalable phytoremediation solutions using native or salt-tolerant plants.
(This activity marked as complete as of this status update)

Activity 2

The field-based phase of this project tested the practical application of salt-tolerant plants, primarily Helianthus annuus (sunflower) and Beta vulgaris (sugar beet), for phytoremediation. Artificial floating islands (AFIs) deployed in a saline pond in St. Paul confirmed these species' salt uptake abilities under natural conditions, though growth was limited by low nutrients. A roadside field trial at Highway 280 showed both species effectively removed Na^+ and Cl^-, with CS accumulating more salt at lower slope positions and SB peaking in the mid-slope area. Monthly monitoring at four sites revealed seasonal variation in salt levels, with the Highway 280 site showing highest salt accumulation during low rainfall. A greenhouse study of five salt hyperaccumulators showed common sunflower (CS) achieved optimal NaCl removal in a 90-day growth period, aligning with seasonal roadside maintenance schedules. Another greenhouse experiment tested CS and three other hyperaccumulators mixed with MnDOT grasses. Results showed improved NaCl extraction over monocultures, especially after introducing fresh hyperaccumulators post-harvest. Across all activities,

findings confirm that sunflower and sugar beet are viable for scalable, seasonal, and site-specific phytoremediation, and that mixing hyperaccumulators with existing plantings can enhance salt removal with periodic replanting.
(This activity marked as complete as of this status update)

Activity 3

This activity explored how salt-tolerant microbes influence the growth and salt accumulation of sunflower and sugar beet in saline hydroponic systems. Three microbial treatments were applied: Penicillium chrysogenum (PC), Pseudomonas fluorescens (PF), and commercial mycorrhizal fungi (MF), all known for salinity tolerance. Plants were grown in a 50 mM NaCl solution for 30 days, alongside uninoculated controls. The results revealed species-specific responses. In sunflowers, PF significantly enhanced growth, likely through improved root interactions and nutrient uptake, whereas PC and MF showed no effect. However, none of the microbes altered sodium (Na^+) or chloride (Cl^-) levels in sunflower tissues, indicating their influence was limited to promoting growth rather than modifying salt uptake. In sugar beet, no microbial treatment significantly affected growth or salt accumulation, suggesting the plant's innate salt tolerance mechanisms overshadowed microbial influence. These findings point to Pseudomonas fluorescens as a promising growth enhancer for sunflowers in saline environments, though not effective for phytoremediation. Meanwhile, sugar beet's resilience appears largely independent of microbial support. Overall, this study highlights the importance of tailoring microbial applications to specific crops and desired outcomes, with future research needed to assess microbial combinations or longer growth periods for potential synergistic effects.
(This activity marked as complete as of this status update)

Dissemination

This sequence of studies explores the use of plants for phytoremediation of salt-contaminated water, progressing from controlled hydroponic experiments to real-world field applications. Initial research presented at the 2023 Bioproducts Symposium introduced hydroponic phytoremediation and established baseline salt-removal efficiencies. Building on those results, the 2024 CFANS Symposium compared plant performance in desalination, followed by further studies presented at the October 2024 Bioproducts Symposium investigating environmental factors that could enhance salt uptake. Most recently, the 2025 CFANS Symposium showcased the field application of artificial floating islands (AFIs), demonstrating the practical potential of this technology for saline water treatment. The next phase, to be presented at the 2025 Climate Change Conference, will highlight AFIs as a scalable, nature-based solution to salt pollution. Alongside these research milestones, the team has engaged in academic outreach, giving a guest lecture in the Spring 2024 BBE 4607 course on industrial biotechnology, sharing insights into NaCl phytoextraction. Additional work on harvesting schedules for optimal salt uptake was also presented in 2025, and a new abstract is in preparation for the 40th Annual Conference on the Environment, focused on enhancing roadside salt removal by integrating salt hyperaccumulators with MnDOT plantings.

Status Update Reporting

Status Update March 1, 2025

Date Submitted: March 1, 2025

Date Approved: March 27, 2025

Overall Update
We are finishing up some experiments in Activity 2 and are working on the activity 3. The experiments include mixing our selected halophytes mixed with MnDOT roadside mix to test their salt uptake behavior and adding microbials to increase the salinity tolerance of roadside plants.

Activity 1
We finished all studies at different culture conditions on the salt uptake and also finished the field tests at 280 site.
(This activity marked as complete as of this status update)

Activity 2
We are working on the effect of different halophytes on the salt uptake when mixing the MN DOT roadside species. We selected the 4 most potential halophyte species based on the previous screening studies, including Common sunflower, Pitseed goosefoot, Showy goldenrod, and Tall fescue turfgrass. We used the MN DOT 25-121 Sandy General Roadside mix and mixed each of the halophytes with the MN DOT recommended roadside species. The aim is to understand how competitive these halophytes will be with other plant species in salt uptake from the soil. We also did monthly cutting of the grass and halophytes and sampling of the soil and plant tissue and analysis of these samples for sodium and chloride content to understand how efficient the salt uptake would be with time. We currently have completed 4 cuttings and are working on the samples processing and analysis.
(This activity marked as complete as of this status update)

Activity 3
At our microbial-assisted on phytoremediation study, Helianthus annuus or common sunflower (CS) was used for this experiment based on the result of the previous experiment. CS were selected because of their ability to grow well in saline conditions and to accumulate salt in their biomass. In these experiments, a commercial fungal strain, Penicillium chrysogenum (ATCC® 10106™) and Penicillium brevicompactum (ATCC® 9056™) and two new fungal strains that previously isolated by our research group, UCS 3 and SFR 5, were tasted for the ability to grow under saline condition. The result shows that the strains can grow very well under 1 M of NaCl. From this test, one strain was selected to be used, which was Penicillium chrysogenum (ATCC® 10106™). We will continue working on the experiments and will also choose Arbuscular mycorrhizal Fungi (AMF) to study their effect.

Dissemination
PhD Sarman Gultom finished his pre-lim exam and now is working on his PhD dissertation. PhD student Leif van Leirop defended his dissertation and finished his PhD on March 1st 2025. We are drafting several manuscripts to disseminate our results. Sarman presented a poster: Gultom, Sarman Oktovianus, and Bo Hu. 2024. Poster presentation: “Impacts of Different Plant Growing Conditions on Salt Phytoremediation.” Presented in the BBE Showcase, October 24th, St. Paul, Minnesota, USA.

Status Update Reporting

Status Update September 1, 2024

Date Submitted: September 1, 2024

Date Approved: October 4, 2024

Overall Update
We are making progress in all activities. In the greenhouse study, we are repeating the growth of all the key species to confirm all our previous findings that these species have great potential for phytoremediation of salt. We are also working to mimic the seed mix from MnDOT recommendation in order to evaluate how competitive our halophytic plants compared to other roadside species. We are working in the field study of hydroponics system at the interception of highway 280 and Energy Drive. We selectively grew several fungi together with halophytic plants to evaluate their assistance in salt uptake.

Activity 1
We had greenhouse experiments on the hydroponics system to study the effects of nutrients on salt uptake. We found that nutrients play an important role in plant growth, but not the ability of the plant to take up salt as the salt concentration in plants are same for all different nutrient treatments. Same observation was found in the harvest time as biomass increases with longer harvesting time but it does not affect Na+ and Cl- concentration in the plant biomass. We filed the application with MnDOT and received approval to work on a field study at Highway 280. The site is a off-road pond with heavy salt pollution (800mg/L). We used artificial floating island design and are growing sunflowers and sugerbeets since May 2024 and water has been sampled to measure the salt concentration. Unfortunately we had severe storm damage on the field site for the hydroponic system at the end of July and we are working to germinate some plant seeds in the greenhouse in order to restore some of the plants on the floating island. The current experimental results will be tested once plant and water samples are all collected.

Activity 2
In the greenhouse, we are studying the effect of harvesting frequency on the salt uptake by 5 different halophytes and now have already completed the harvest at 120 days. We are developing a seed mixing of halophyte species with the MnDOT roadside species for enhancing salt uptake and experiments. We also conducted a greenhouse experiment to study the effect of different halophytes on the salt uptake when mixing the MN DONT roadside species. We selected the 4 most potential halophyte species based on the previous screening studies, including Common sunflower, Pitseed goosefoot, Showy goldenrod, and Tall fescue turfgrass. We used the MN DOT 25-121 Sandy General Roadside mix and mixed each of the halophytes with the MN DONT recommended roadside species.

Activity 3
Ongoing research within our lab include two species of wild fungal species we screened and two fungi species we found from the references. We are using hydroponics system to study the possible improvement for these fungi to enable plants more tolerant to salt conditions and even their assistance in salt uptake.

Dissemination
Gultom, Sarman Oktovianus, and Bo Hu. 2024.“Salt Phytoremediation of Selected Plants in Hydroponic Systems.” Presented at the CFANS Research Symposium, March 14, St. Paul, Minnesota.

Status Update Reporting

Status Update March 1, 2024

Date Submitted: March 1, 2024

Date Approved: May 8, 2024

Overall Update
Project work to date includes that primarily on Activity 1 and 2 of the workplan. We worked both on the soil experiments and hydroponics systems. Planting of identified halophyte species and collection of soil samples at a field research site located at the intersection of Highway 280 and Energy Park Drive in Saint Paul Minnesota served to meet objectives defined under two project milestones as detailed below. Hydroponic study in the greenhouse was focused on the different environmental conditions on the plants to remove salt from water.

Activity 1
Our field study with MnDOT at Highway 280 finished in September 2023. The results showed that both common sunflowers and sugar beets grew well with a large biomass production. The net uptake of sodium (Na) and chloride (Cl) in CS showed an increasing trend when the growing level goes lower and could reach up to 429.2 mg and 8732.4 mg, respectively. The net uptake of Na and Cl in SB reached the highest (up to 3599 mg and 6165 mg, respectively) in the middle slope.

For the hydroponic study, we studied the effect of different salt concentrations on salt uptake. The NaCl concentration in the water solution decreased for all salt treatments and all plants. Sugar beet uptake more salt than other plants and common sunflower showed greater biomass production than other plants. The decreasing amount of salt in the water solution is mainly caused by the capability of plants to uptake the salt. The pattern shows that the accumulation of Na and Cl in all plants' tissues increases with an increase in the salt treatment. Chloride was more readily taken up by the plants and translocated to the above-water biomass.

Activity 2
We are working on the ecological design of a rain garden to investigate its effect on salt uptake. We will follow the instruction of University of Minnesota Extension, building a rain garden (https://extension.umn.edu/landscape-design/rain-gardens#choose-plants-1778663) and add the halophyte species we screened from our previous work. We will also examine the factors of designing the rain garden (shape, size, location, species, etc.) and optimize the design to achieve the most efficient salt uptake performance. In the greenhouse, we are studying the effect of harvesting frequency on the salt uptake by 5 different halophytes and now have already completed the 5th harvest. We are developing a seed mixing of halophyte species with the MnDOT roadside species for enhancing salt uptake and experiments.

In the meantime, we studied the Effect of plant ratio (CS: SB ratio) on salt uptake in hydroponic systems. Two potential plants common sunflower (CS) and sugar beet (SB) were chosen for removing salt from salt-contaminated water. The result shows that the combination of CS and SB (2:2 ratio) has taken the highest salt into their biomass.

Activity 3
Ongoing research within our lab characterizing various plant growth-promoting bacteria, arbuscular mycorrhizal fungi, and non-mycorrhizal fungi will inform preliminary species selection in identifying key microbial taxa and genes involved in microbially-mediated roadside plant salt tolerance and assimilation.

Dissemination

Leif defended his PhD dissertation on December 8th, 2023. He is preparing manuscripts to be submitted.

Sarman made a poster presentation: Gultom, Sarman Oktovianus, and Bo Hu. 2023.“Study of Salt-Removal Phytoremediation on Hydroponics.” Presented at the BBE Annual Fall Showcase, October 26, St. Paul, Minnesota.

Status Update Reporting

Status Update September 1, 2023

Date Submitted: August 31, 2023

Date Approved: September 27, 2023

Overall Update
We had been working with MnDOT, communicating with our results and also finalizing a new testing site off the ramp at highway 280 and Energy Drive in St Paul. This site is only a few minutes away from our lab, very convenient, and has many features that we want to test, for instance, a slope and potential pond nearby. We have been working in greenhouse studies and field tests to study the plant behavior, started to work on the ecological designs for possible better deployment, and study the microbial plant interactions for possible fertilization effects.

Activity 1
We have been working in both greenhouse studies and field tests. Our greenhouse study focused on both soil growth tests and hydroponics. The soil growth study includes different cutting and harvesting methods for some promising plant species. We also extended our screening to more perennial species. Our results showed that cutting sugar beets regularly does not affect salt accumulation, but cutting the sun flower will affect the plant growth if the cutting shoots are too low. The overall salt accumulation per plant remains same whether or not if we cut it in the middle, therefore it is recommended to wait until the fall to harvest all plant biomass. We also screened some perennial species, like perennial sun flowers, but it seems that the best strain is still annual sun flower. This has also been confirmed through the oral communication based on the observation by MnDOT staff. We worked on hydroponics to screen some species that can work in the water environment, and we found out that there are several species showing promising results. We took some water from the pond near our 280 testing site, which showed very elevated NaCl concentration, and we are using that water for growth tests.

Activity 2
We start to plan some ecological designs for deployment method study. We are testing the salt concentration change on the plant salt accumulation in the hydroponics system.

Activity 3
We used some fungal strains to evaluate whether they can assist the salt uptake. The results still need to be further tested.

Dissemination
Leif gave an oral presentation to the Minnesota Erosion Control Association in St Clouds, MN to report what we have found out from our experiments on January 24th to 26th, 2023. Leif gave a poster presentation at the ASABE Annual International Meeting (AIM) in Houston, Texas between 17-20 July, 2022. We had a meeting with MnDOT to update our results and MnDOT has helped us to find a better testing site at highway 280 ramp.

Status Update Reporting

Status Update March 1, 2023

Date Submitted: February 13, 2023

Date Approved: February 21, 2023

Overall Update
Project work to date includes that primarily on Activity 1 of the workplan. Planting of identified halophyte species and collection of soil samples at a field research site located at the intersection of Highway 280 and Energy Park Drive in Saint Paul Minnesota in November of 2022 served to meet objectives defined under two project milestones as detailed below.

Activity 1
1. Field study of halophytes growing with native roadside plants.

Potential plant species for phytoremediation were grown in a field study this summer at two locations on and near the St. Paul University of Minnesota campus. One site was near the campus on Larpenteur Avenue. The other site was on the roadside of Gortner Avenue. We have also worked with Minnesota Department of Transportation staff to identify and obtain access to a field research site for planting of halophytes with established roadside vegetation and a significant slope where salt may likely be accumulating at the lower portion. This MnDOT field site is located at the intersection of Highway 280 and Energy Park Drive in St. Paul Minnesota. Two halophyte species were included for planting based on previous greenhouse and laboratory work including sugar beet and common sunflower.

2. Adaptation of halophytes to different types of roadside soil.

Plots were established on MnDOT site to capture a greater range of soil types and environmental conditions. Soil samples were collected to a depth of approximately six inches at established locations along the elevation gradient. Soil sampling will continue bi-weekly or monthly as conditions allow, for laboratory analysis of sodium and chloride.

Activity 2
No significant progress to report upon for Activity 2 at this time.

Activity 3
1. The study of selected microbial community to tolerate high salt environment and possible assimilation into cells.

Ongoing research within our lab characterizing various plant growth-promoting bacteria, arbuscular mycorrhizal fungi, and non-mycorrhizal fungi will inform preliminary species selection in identifying key microbial taxa and genes involved in microbially-mediated roadside plant salt tolerance and assimilation.

Dissemination
No dissemination activity to report upon at this time as project results and conclusions are still in progress.