

Utah (Utah State University) Annual Report - FY2022

Report Status: Approved as of 06/28/2023

Contributing Organizations

Utah State University

Executive Summary

Overview

Utah State University Extension

Utah State University (USU) Extension delivers relevant information, education, and solutions to individuals, families, and communities across Utah. USU Extension provides research-based education and information on agriculture and natural resources, home gardening, family well-being, relationship education, food nutrition and safety, emergency preparedness, community development, and youth programs. USU Extension plays a primary role in helping Utah State University fulfill its land-grant mission. Though more than 100 years old, USU Extension is as important as ever due to the increased diversity and complexity of the issues affecting Utah residents.

The integration of teaching, research, and public service enables USU Extension to respond to critical and emerging issues with research-based, unbiased information. USU Extension focuses on seven (7) critical issues, as defined by NIFA, these are (1) Global Food Security and Hunger, (2) Climate Change and Management of Natural Resources, (3) Nutrition and Health, (4) Food Safety, (5) Healthy, Financially Secure Families, (6) Youth Development, and (7) Community Resilience.

Table 1: Summary of Critical Issues

<i>Critical Issue</i>	<i>Description and Objectives</i>	<i>Major Program</i>
Global Food Security and Hunger	We must develop more stress-resistant crops and ensure an improvement in overall agricultural productivity. The objective of USU Extension is to enhance Utah's food security through productive and sustainable agricultural systems.	Agricultural Productivity
Climate Change and Management of Natural Resources	Agriculture is climate dependent; any changes in the environment will require that plants and animals adapt to climate change. The objective of USU Extension is to be at the forefront in adapting to new climate realities, as well as mitigating many of the influences of climate change.	Sustainable Natural Resources Education
Nutrition and Health	Many of the most vulnerable populations, such as young children and aging adults, are subject to food scarcity and poor diets. The objective of USU Extension is to enable a healthy population through education on affordable and nutritious diets and healthy living.	Public Nutrition and Health Education

Food Safety	Pathogens can enter the food supply during the production, harvest, processing, and transporting process. The objective of USU Extension is to reduce foodborne illnesses through education on proper food preparation, storage, preservation, and canning.	Public Food Safety Education
Healthy, Financially Secure Families	Utah families face high debt loads, rural-urban migration, and high divorce rates. The objective of this program is to enhance individual and family resource management. Other aspects include healthy marital and family relationships, and mental health and well-being.	Individual and Family Resource Management
Youth Development	Youth development is critical to the future prosperity of Utah. Utah 4-H of USU Extension actively builds the knowledge, skills, and attitude of youth to prepare them for a successful life. The objective of USU Extension is to facilitate positive youth development to ensure a bright future for youth.	Utah 4-H: Positive Youth Development
Community Resilience	Community resilience and development through economic prosperity and social capital are necessary to strengthen urban and rural communities. The objective of USU Extension is to promote community resilience through sound community planning, youth and adult education, recreation, and family support services.	Vibrant Communities

USU Extension is committed to improving the lives of Utahns through non-formal education. Therefore, it is necessary to continuously monitor and demonstrate our impact on individuals and communities across the state. Outreach programs for each *Critical Issue* are aligned to key social, economic, and/or environmental (SEE) conditions. Program impact is assessed through changes in behavioral indicators that reflect SEE conditions. Statewide program evaluation activities are geared towards measuring changes in individual and community behaviors that correlate to improved quality of life for Utahns.

Utah Agricultural Experiment Station

The Utah Agricultural Experiment Station supports diverse research programs in six of the eight colleges at Utah State University: the College of Agriculture and Applied Sciences, the Quinney College of Natural Resources, the College of Sciences, the College of Engineering, the Emma Eccles Jones College of Education and Human Services, and the College of Humanities and Social Sciences. In 2022, UAES supported scientists engaged in 89 Hatch Projects, 31 Hatch Multistate Projects, 15 McIntire-Stenis Projects, 3 Animal Health Projects, and 76 State Funded Projects. Many of these research projects, particularly the projects where the PI is also an Extension Specialist, generate new information that directly informs our Extension Programs.

Critical Issue: Climate Change and Management of Natural Resources

Major Extension Program: Sustainable Natural Resources

Program Goal: To provide non-formal education to residents, stakeholders, and organizations to promote, facilitate, and strengthen environmental stewardship and sustainable natural resource use in Utah. This project primarily focuses on forest management, water conservation, and stewardship of public lands.

Desired Program Outcomes:

1. To equip residents with the competency to effectively engage in natural resource conservation and preservation.
2. To facilitate partnerships between community members and public and private stakeholders to strengthen natural resource conservation and enable sustainable resource use.

Notable Results in FY22:

- **Water Quality Education: Pack it Out Utah**
 - Between 2021 to 2022, Pack it Out Utah collaborated with partner organizations to host local clean-up events for volunteers. There were 12 local clean-up events which played a significant role in the increase of participation and garbage cleaned up.
 - To date, Pack It Out Utah volunteers have removed more than 11,000 pounds of trash from Utah's public lands and waterways.
 - Volunteer hours were valued at \$42,924 with 1,504 hours based on a volunteer hourly rate of \$28.54.
- **Forecasting and Adapting to Drought: 2022 Spring Runoff Conference**
 - The Spring Runoff Conference convened university experts, federal and state agencies, natural resource managers, and community members to share cutting-edge research on drought forecasting and conservation practices and community strategies for adapting to drought through water-efficient practices.
 - During five (5) hours of educational activities facilitated by USU Extension, there were also 12 presentations from two (2) federal agencies, and four (4) state agencies.
 - Participants (74%) reported knowledge gain in one or more topics about drought as a result of attending the conference, about 40% of participants indicated they gained knowledge about federal, state, and local drought response and perspectives, 49% indicated they gained knowledge about the impacts of drought in the Colorado River, and 47% indicated they gained knowledge about innovations in forecasting drought.
 - As a result of the conference, about 36% of participants reported they intend to use water optimization practices, 55% reported they intend to consider the collection and use of graywater, and 70% reported they intend to encourage community response to drought through everyday practices.

Utah Agricultural Experiment Station

Climate Change and Management of Natural Resources is a major research area for the Utah Agricultural Experiment Station. In 2022 there were 28 Hatch projects, 8 Hatch Multistate projects, 15 McIntire-Stennis projects, plus additional projects funded by state matching funds, that addressed this Critical Issue. Descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Community Resilience

Major Extension Program: Vibrant Communities

Program Goal: To strengthen communities across Utah through facilitated community-focused coalitions and partnerships, entrepreneurship education, and strategic initiatives to facilitate economic and social wellbeing.

Desired Program Outcomes:

1. To connect rural communities to economic opportunities in urban centers through innovative workplace practices.
2. To facilitate educational interventions, and community partnerships and coalitions to reduce substance abuse disorders in rural counties.

Notable Results in FY22:

- **Suicide Prevention: VitalCog Training Series**
 - USU Extension facilitated VitalCog to educate and equip businesses with the capacity to address mental health and suicide concerns in the workplace.
 - A total of 10 virtual training sessions were conducted with 87 participants.
 - Short-term evaluation results indicated that attendees had an increase in knowledge related to suicide and suicide prevention in the workplace following the training (89%).
 - Most participants reported an improved level of confidence about talking to someone about getting help following the training (92%). Participants agreed they would be able to apply the information they learned in their place of work (88%). One of the most commonly reported concepts learned was to be direct when asking about suicide.
- **Economic Development: Certified Remote Work Professional Course (CRWP)**
 - In 2022, the CRWP's annual evaluation results showed that 35% of the sample of participants found remote work.
 - Total salaries for those who found remote work increased by 73%, and 69% believed their median salaries would likely increase by 20% over the next year.

- With remote work, commutes to a physical workplace decreased by 62%. This resulted in an 83% total reduction in the number of miles driven by all participants who found remote work. The reduction in total miles driven equated to fuel savings of \$81 for all participants who found remote work.
- The reduction in the total number of miles driven was equivalent to a total reduction of 0.18 metric tons of carbon emissions.

Utah Agricultural Experiment Station

Community Resilience is a minor research area for the Utah Agricultural Experiment Station. In 2022 there were three Hatch projects, two Hatch Multistate Projects, plus additional projects funded by state matching funds, that addressed this Critical Issue. Descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Food Safety

Major Extension Program: Public Food Safety Education

Program Goal: To provide relevant research-based education to Utah residents on best practices to reduce the risk food contamination and foodborne illnesses. Major focus areas of this program are food preservation techniques and household food storage.

Desired Program Outcomes:

1. To reduce the occurrences of foodborne illnesses in Utah through research-based education on food safety practices in households
2. To reduce food contamination in the food supply chain by providing relevant education on best practices to processors and producers.

Notable Results in FY22:

- Food Storage: Introductory Canning 101
 - In 2022, USU Extension hosted a Canning 101 series on food canning and preservation. Over 100 individuals participated in the series.
 - Results showed 97% of participants used the food preservation resources provided, 79% explored information on USU Extension's website, 45% checked if the food preservation resources they had at home are up to date, 73% followed research-based directions provided by USU Extension and the USDA.
 - Results suggest the food preservation education provided by USU Extension will prevent food-borne illnesses.
- Food Preservation: Hands-on Canning Classes
 - The Basics of Home Canning Class targeted individuals who were new to canning, and topics included food safety, safe recipes, canning methods, and storing canned goods. A total of 78 participants attended this class.
 - The hands-on classes led to an increase in participants' confidence and skills to practice safe canning techniques at home. In the Master Food Preserver Training, participants demonstrated an increase in knowledge and skills to adopt proper canning techniques to safely can on their own.

Utah Agricultural Experiment Station

Food Safety is an important research area for the Utah Agricultural Experiment Station. In 2022 there were five Hatch projects, three Hatch Multistate Projects, plus additional projects funded by state matching funds, that addressed this Critical Issue. Descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Global Food Security and Hunger

Major Extension Program: Agricultural Productivity

Program Goal: To meet the needs of traditional agriculture while evolving to meet the needs of developing agricultural industries.

Desired Program Outcomes:

1. To increase the productivity and efficiency of Utah agricultural operations.
2. To promote sustainable natural resource use through relevant education on conservation practices.

Notable Results in FY22:

- Beekeeping Education: Thriving Hives
 - The Thriving Hive Beginning Beekeeping program was offered to individuals interested in beekeeping.

- Evaluation results showed a significant improvement in participants' knowledge of all topics, specifically Varroa mites, and the services performed by the county bee inspector after the series.
- Participants indicated strong intentions to implement Varroa mite management practices.
- Residential Gardening: Preventing Injury Among Master Gardeners.
 - The Adaptive Gardening and Minimizing Injury with Tools, Techniques, and Stretches workshop teaches participants best practices, proper postures, and correct tool use to help prevent and minimize pain and injury while engaging in common gardening activities.
 - Participants improved their knowledge of all three major concepts; best practices for gardening, safe movement in gardening, and stretches and exercises to ease pain and discomfort.
 - Most participants adopted recommended practices for gardening behaviors related to using proper stances and stretching.
- Agricultural Literacy: Utah Agriculture in the Classroom (UTIC) Teacher Seminar
 - The Utah Agriculture in the Classroom (AITC) program seeks to increase pre-service teachers' agricultural literacy.
 - Results showed 70% of the participants indicated they agreed or strongly agreed their agricultural knowledge increased after the seminar. Most participants (98%) stated it was likely or very likely they would use the resources provided in the seminar and explore the Utah AITC website for further resources.
- Diversity and Inclusion: Inclusive Farmers Markets
 - The Utah Farmers Market Network (UFMN) prioritized exploring how farmers' markets could be more welcoming and inclusive to all individuals regardless of racial background.
 - Evaluation results indicated all participants had an increased understanding of the demographic makeup and lived experience of the underserved audiences.
 - Many participants reported a more developed frame of reference concerning issues of DEI, which permeated their personal and professional lives. One participant said, "I feel like I have a whole new lens - I now see things in a different light and am aware of injustice happening around me."
- Agricultural Inputs: IPM Demonstration Farms.
 - The IPM program established a vegetable IPM farm to test and demonstrate various IPM techniques for vegetable production.
 - There was an improvement in participants' knowledge of all IPM topics covered in the workshops. Results indicated there was a 73% increase in participants' knowledge of general IPM tactics, a 78% increase in row cover use to control pests, a 100% increase in trap crop/companion planting, a 32% increase in weed control methods, and 65% increase in pest identification.

Utah Agricultural Experiment Station

Global Food Security and Hunger is the largest research area for the Utah Agricultural Experiment Station. In 2022 there were 42 Hatch projects, 16 Hatch Multistate Projects, 3 Animal Health projects, plus additional projects funded by state matching funds, that addressed this Critical Issue. Descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Healthy, Financially Secure Families

Major Extension Program: Individual and Family Resource Management

Program Goal: To enhance individual and family resource management (FRM). FRM relates to financial management, family health, healthy marital and family relationships, and mental health and wellbeing.

Desired Program Outcomes:

1. To strengthen family relationships.
2. To improve the economic wellbeing of individuals and families.

Notable Results in FY22:

- Strengthening Marital Relationships
 - USU hosts the Utah Marriage Commission and manages the Temporary Assistance for Needy Families. This includes Bi-weekly webinars from relationship and marriage experts on a variety of topics.
 - Results indicated that more than 96% of webinar respondents agreed they had more knowledge and skills related to healthy relationships, were more committed to forming/maintaining healthy relationships, and had more knowledge/ability to recognize unhealthy relationships
- Homeownership: Homebuyer Education

- The USU Extension Homebuyer Education courses are HUD-approved and USDA Rural Housing approved. Between 2020 and 2022, there were 1,384 participants in the English Course and 15 participants in the Spanish course.
 - After completing the homebuyer course, 82% of participants established emergency savings, 86% utilized the revolving savings strategy, and 86% saved 1% of the home's value per year for repairs.
 - A follow-up survey indicated 50% of participants in the homebuyer course contributed to their success in purchasing a home.
- **Women's Wellbeing: The Celebrating Women Conference**
 - USU Extension hosts the Celebrating Women Conference which addressed various aspects of wellness: mental wellness, financial wellness, stress management, positivity, and cultivating balance, while providing opportunities for women to connect.
 - Results of the 2022 Celebrating Women Conference showed 100% of respondents were likely to make a positive change as a result of participating in the conference, such as prioritizing their time, setting boundaries, asking for help, changing their mindset, practice intuitive eating, speaking and being kinder to themselves or adjust their mental attitude.
 - Most participants (93%) agreed the conference gave them strategies to improve their life, 93% agreed they want to make positive changes to their life, and 93% agree they expect that what they have learned will benefit their well-being.
- **Finance Education: Family Finance Education**
 - USU Extension facilitated train-the-trainer events on finance education to 54 Extension faculty and community leaders in Utah.
 - Results indicated that 93% had an improved understanding of financial wellness, and 96% intend to make positive changes to their personal finance practices.

Utah Agricultural Experiment Station

Healthy, Financially Secure Families is a minor research area for the Utah Agricultural Experiment Station. In 2022 there were one Hatch project, one Hatch Multistate Project, plus additional projects funded by state matching funds, that addressed this Critical Issue. The descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Nutrition and Health

Major Extension Program: Public Nutrition and Health Education

Program Goal: To decrease the incidences of chronic diseases and other nutrition-related health issues among residents through non-formal nutrition education. The priorities for this program are to expand nutritional research and education, and to promote healthy dietary habits.

Desired Program Outcomes:

1. To empower residents to make healthy food choices and improve their nutritional intake.
2. To reduce the economic cost of chronic diseases in Utah.

Notable Results in FY22:

- **Diabetes Awareness: Diabetes Prevention and Management**
 - USU Extension sought to reduce the burden of preventable diabetes among adults in Utah via a "Food as Medicine" webinar series. The public diabetes programs highlighted the National DPP, Diabetes Self-Management Education and Support (DSMES) Toolkit, and Walk with Ease (WWE) program.
 - After attending the workshops, evaluation results indicated 28% of participants were likely to enroll in the National DPP; 44% were "extremely likely" or "somewhat likely" to enroll in DSMES, and 50% stated that they were "extremely likely" or "somewhat likely" to enroll in WWE.
- **Chronic Diseases: Diabetes Prevention**
 - USU Extension expanded the focus on a diabetes education program. The Diabetes Cook Along Classes were piloted in Box Elder and Cache County, then expanded in 2022 to two other counties. The 4-week in-person diabetes education program combined lecture-based learning and hands-on cooking experience
 - Results indicated all participants experienced an increase in knowledge of the concepts covered in the curricula.
 - Most participants also reported positive changes to their lifestyle behaviors (e.g., checking blood sugar levels daily, exercising daily, taking medication as prescribed, and limiting carbohydrate intake daily).
- **Food Security: Create Better Health (CBH)**

- Create Better Health Utah (CBH) offers group nutrition education classes to adults and youth, implements policy, systems, and environmental strategies to improve healthy food access for low-income audiences.
- Adult participants intended to stretch their food dollars to last the month more often, choose a variety of foods based on MyPlate more often, intended to be physically active for at least 5 days a week, and intended to adjust their meals to use foods on hand more often.
- Youth participants in 1st and 2nd grade improved their recognition of healthy snacks, fruits, and dairy foods. Youth in 3rd - 6th grade reported eating more vegetables, fruits, and healthy snacks. Youth also reported an increase in physical activities and hand washing before eating.

Utah Agricultural Experiment Station

Nutrition and Health is an important research area for the Utah Agricultural Experiment Station. In 2022 there were 10 Hatch projects, plus additional projects funded by state matching funds, that addressed this Critical Issue. Descriptions and results for these research projects are included in the results section of this report.

Critical Issue: Youth Development

Major Extension Program: Utah 4-H: Positive Youth Development

Program Goal: To empower youth success through hands-on projects in educational areas including science, health, agriculture, and civic engagement. Utah 4-H allows youth to engage in their educational interests in a positive environment where they receive guidance from adult mentors, while also being encouraged to take on leadership roles.

Desired Program Outcomes:

1. To facilitate positive youth development through educational activities that fosters youth competence, character, connection, caring, confidence, and contribution
2. To empower youth to pursue their passion for a successful career and healthy life.

Notable Results in FY22:

- Impact of Utah 4-H
 - Through Utah 4-H, USU Extension is actively engaged in youth development programming to improve the overall wellbeing of Utah's youth.
 - Results showed the majority of youth who attended 4-H learned about responsibility, teamwork, leadership, communication skills, problem-solving, goal setting, concern for others, and healthy lifestyle choices.
 - Youth with higher engagement in Utah 4-H were about 3 times more likely to learn about responsibility, 98% more likely to learn about problem-solving, almost 2 times more likely to learn about goal-setting, 98% more likely to learn about concern for others, and 96% more likely to learn about being responsible for their actions.
 - Compared to those with lower engagement, youth with higher engagement in Utah 4-H experienced a 25% increase in their concern for others, a 22% increase in their goal-setting skills, and a 16% increase in their problem-solving skills.
 - Youth with higher engagement in Utah 4-H were 70% more likely to demonstrate higher Competence, 89% more likely to demonstrate higher Character, 80% more likely to demonstrate higher Connection, 97% more likely to demonstrate higher Caring, almost 2 times more likely to demonstrate higher Confidence, and 92% more likely to demonstrate higher Contribution.
 - Compared to those with lower engagement, youth with higher engagement in 4-H had a 31% increase in their skills related to confidence, a 28% increase in their contribution, and a 23% increase in their caring.

Utah Agricultural Experiment Station

Youth Development is a minor research area for the Utah Agricultural Experiment Station. In 2022 there was one Hatch Multistate project, plus additional projects funded by state matching funds, that addressed this Critical Issue. The description and results for this research project are included in the results section of this report.

Merit and Scientific Peer Review Processes

Updates

No changes from Plan of Work.

Stakeholder Input

Actions to seek stakeholder input that encouraged their participation with a brief explanation

No changes from Plan of Work.

Methods to identify individuals and groups and brief explanation

No changes from Plan of Work.

Methods for collecting stakeholder input and brief explanation

No changes from Plan of Work.

A statement of how the input will be considered and brief explanation of what you learned from your stakeholders

Utah State University Extension

Several state-level and county-level needs assessments were conducted between 2019 and 2022. These include a youth needs assessment, and research to understand the perceptions of county commissioners on issues affecting residents. Primary data from clientele (youth and adult), county commissioners, and other stakeholders were used to develop, implement, and evaluate Extension programs within the current Plan of Work. Each program was aligned to an identified need, activities were implemented to target the need, and evaluation frameworks were developed to measure progress towards addressing the need. In addition, program teams and working groups utilized formative evaluation methods for continuous program improvement, while also working with target audiences to adjust program components. Therefore, stakeholder input is considered and incorporated in every stage of the program planning and evaluation process at USU Extension.

Utah Agricultural Experiment Station

Faculty, Department Heads, and Utah Agricultural Experiment Station (UAES) Administrators meet with a wide array of stakeholders including commodity groups, industry partners, state agency scientists and administrators, state legislators, and NIFA National Program Leaders on a regular basis. Research priorities are frequently a topic of discussion at these meetings. Faculty members set their research priorities based on discussions with their department head, their dean, their college's associate dean for research, and the Director and/or Associate Director of the UAES. Faculty members develop their own research objectives for their five-year UAES (Hatch, McIntire-Stennis, Animal Health, or State) research projects. However, these projects are reviewed by their department head, two content experts, and the Associate Director of the UAES, and must align with NIFA Strategic Goals and the USU Critical Issues defined in our Plan of Work.

Highlighted Results by Project or Program

Critical Issue

Climate Change and Management of Natural Resources

Increasing wetland plant restoration capacity in Utah through plant material development, manager surveys, and experiments.

Project Director

Karin Kettenring

Organization

Utah State University

Accession Number

7002863



Increasing wetland plant restoration capacity in Utah through plant material development, manager surveys, and experiments

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The **broad goals** of this **5-year project** are to increase capacity for wetland plant restoration in Utah and the Intermountain West.

The **specific objectives** of the **first year** of the project will be to:

(1) General wetland restoration capacity:

- *to determine wetland managers' common wetland revegetation practices and obstacles they face in the Intermountain West
- *to evaluate best practices for seeding and planting while simultaneously sharing knowledge with wetland stakeholders

(2) Aquatic wetland plant restoration capacity:

- *to build a collection of at least 7 aquatic plant species (submerged and floating leaved)
- *to develop a draft aquatic plant identification guide
- *to evaluate different methods for reintroducing aquatic plants into restorations

(3) Emergent wetland plant restoration capacity:

- *to build a collection of emergent plant seeds
- *to develop draft seed viability testing protocols
- *to screen the collected species for seed and seedling functional traits

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Below I describe the major accomplishments from this first year related to our project objectives.

(1) General wetland restoration capacity:

*determine wetland managers' common wetland revegetation practices and obstacles they face in the Intermountain West
>>ACCOMPLISHMENTS: We completed our survey of wetland managers (n = 52) and are in the final stages of data analysis and synthesis. This work was led and largely accomplished by Senior Research Technician Rae Robinson with collaborations from Kate Sinnott, Emily Tarsa, Annie Henry, Adrienne Ernst, and Mark Brunson.

*evaluate best practices for seeding and planting while simultaneously sharing knowledge with wetland stakeholders
>>ACCOMPLISHMENTS: We initiated a wetland restoration demonstration project to evaluate best practices for seeding and planting (through the establishment of experimental plots).

We also simultaneously shared revegetation knowledge with our field tour in September 2022 with ~40 wetland managers from northern Utah representing all the various wetland stakeholders in the region (e.g., USFWS; UT Geological Survey; UT Division of Forestry, Fire & State Lands; UT Division of Wildlife Resources; Bureau of Reclamation; Ducks Unlimited; Audubon; The Nature Conservancy; USU and BYU academics; and private duck club owners).

(2) Aquatic wetland plant restoration capacity:

*build a collection of at least 7 aquatic plant species (submerged and floating leaved)
>>ACCOMPLISHMENTS: We built the mesocosms to house the plant species and then collected (and decontaminated) 28 populations spanning 14 aquatic plant species from throughout the region. This work was led and largely accomplished by MS student Kate Sinnott.

*develop a draft aquatic plant identification guide
>>ACCOMPLISHMENTS: We drafted the guide, solicited reviews from many stakeholders, refined the guide multiple times, and are now poised to submit it for formal peer review. This work was led and largely accomplished by MS student Kate Sinnott.

*evaluate different methods for reintroducing aquatic plants into restorations
>>ACCOMPLISHMENTS: We conducted two experiments in the field at the Provo River Delta Restoration Project looking at different types of plugs and different types of cuttings for their effectiveness in reestablishing native plants. These data are now being analyzed and synthesized for Kate Sinnott's MS research.

(3) Emergent wetland plant restoration capacity:

*build a collection of emergent plant seeds

>>ACCOMPLISHMENTS: Our research crew spent hundreds of hours collecting native seeds from throughout the Great Salt Lake Watershed and we collected 35 species to use in our experiments this next year.

*develop draft seed viability testing protocols

>>ACCOMPLISHMENTS: We have drafted seed viability testing protocols for these species and will refine these methods this winter.

*screen the collected species for seed and seedling functional traits

>>ACCOMPLISHMENTS: We have conducted/continue to conduct a number of experiments related to seed and seedling functional traits for these species. We are currently summarizing these data and will have more complete reports for this next reporting period.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The main target audiences are Intermountain West restoration practitioners, wetland managers, native plant vendors, and wetland researchers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

There are no changes to the overall work plan.

Training and Professional Development:

The project is providing opportunities in ecological experimental design, data collection, analysis, presentation, and synthesis for graduate students (Kate Sinnott; Emily Tarsa), staff scientists (Rae Robinson; Adrienne Ernst; Annie Henry) and undergraduate technicians (Nate Crawford, Steph Aristizabal, Grace Greenelsh). Students practiced their data presentation and synthesis skills when they presented to the USU wetland research-practitioner working group in November 2022.

Dissemination:

Students presented to the USU wetland research-practitioner working group in November 2022. We also summarizing our research findings in a number of grant reports to state agencies and through outreach publications.

Other Products:

Data and Research Material - Survey wetland managers in the Intermountain West to determine their common wetland revegetation practices and obstacles they face.

>>PRODUCT: We have a near-final dataset on managers' practices and challenges from this survey. We have conducted basic data analysis and synthesis but await just a couple more survey responses to finalize this data synthesis.

Data and Research Material - Initiate a wetland restoration demonstration project to evaluate best practices for seeding and planting.

>>PRODUCT: We have a dataset from year 1 of this seeding and planting effort.

Physical Collections - Build a collection of at least 7 aquatic plant species (submerged and floating leaved) sourced from throughout the Intermountain West to be grown in “mother colonies” at the USU Millville Aquatic Research Facility (MARF).
>>PRODUCT: We have 28 collections spanning 14 aquatic plant species established in mother colonies at MARF. Species established are *Ceratophyllum demersum* (3 populations), *Chara* sp. (1 population), *Lemna triscula* (1 population), *Myriophyllum sibiricum* (1 population), *Myriophyllum spicatum* (1 population), *Najas marina* (1 population), *Potamogeton crispus* (1 population), *Potamogeton foliosus* (1 population), *Potamogeton nodosus* (2 populations), *Ranunculus aquatilis* (3 populations), *Ruppia cirrhosa* (1 population), *Stuckenia pectinata* (7 population), *Utricularia vulgaris* (1 population), and *Zannichellia palustris* (4 populations). Main collection sites include Farmington Bay WMA, Fish Springs WMA, Utah Lake, Hobbie Creek, the Provo River, and Mill Race.

Other - Develop a draft aquatic plant identification guide to aid in the future collection, propagation, and restoration of aquatic plants in the region.

>>PRODUCT: We have a near-final draft of the plant guide that will be submitted for formal peer review this week.

Data and Research Material - Evaluate different methods for reintroducing aquatic plants into wetland restorations.

>>PRODUCT: We have a dataset on the effectiveness of different plug and cutting reintroduction techniques for aquatic plant establishment and cover.

Physical Collections - Build a collection of emergent plant seeds for at least 30 native species sourced from the Great Salt Lake Watershed.

>>PRODUCT: We have seeds from 35 native wetland species for use in our experiments, including 2 species that are new in 2022: *Allenrolfea occidentalis* and *Suaeda calceoliformis*

Protocols - Develop draft seed viability testing protocols for the 35 emergent plant species.

>>PRODUCT: We have a draft seed viability testing protocol that we will finalize this winter with additional testing.

Data and Research Material - Screen the collected species for seed and seedling functional traits likely to drive plant establishment and invasion resistance in wetlands.

>>PRODUCT: We have a dataset on native seed and seedling functional traits for some of these 35 species.

Plan of Work:

In this next work period, we will continue to address the following objectives with the following experiments and studies:

(1) General wetland restoration capacity:

Finish analyzing and synthesizing our data from the survey of wetland managers in the Intermountain West to determine their common wetland revegetation practices and obstacles they face. Draft manuscript for peer-reviewed publication. Share results with stakeholders.

Conduct vendor survey that mirrors the wetland manager survey.

Collect data on plant performance in the seedlings and plantings in the wetland restoration demonstration project.

(2) Aquatic wetland plant restoration capacity:

Maintain the collection of the aquatic plant species at MARF. Add new species or populations as needed to meet experimental / restoration needs.

Review the aquatic plant identification guide in response to peer review feedback during the formal review process. Publish, print, and disseminate the guide.

Synthesize data from the 2022 experiments and design new experiments based off of the 2022 results.

(3) Emergent wetland plant restoration capacity:

Use the collection of emergent plant seeds for 2023 experiments; collect new batches of seeds in 2023 as needed.

Further refine and publish the seed viability testing protocols.

Screen the collected species for seed and seedling functional traits likely to drive plant establishment and invasion resistance in wetlands.

Project Director

Yoshi Chikamoto

Organization

Utah State University

Accession Number

7002874



Climate Impact on Prolonged Drought Forecast and Subsequent Natural Disasters in American West

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

A primary goal of this project is to reveal a physical process of how the large-scale climate dynamics affect prolonged drought conditions and following natural hazards, such as intense wildfire and poor air quality in the American West. Specifically, this project focuses on the remote impact of tropical ocean forcing on hydroclimate variability in Utah. By utilizing the concept of weather regimes, this project identifies the dynamic process to connect the ocean precursors with Utah's hydrological responses to establish a reliable drought forecasting system on a longer lead time. Project outcomes will help the decision-making process for stakeholders and water resource managers to mitigate the upcoming drought threats.

To achieve the goal, this project proposes five objectives:

Objective 1: Identify weather regime impacts on drought-induced threats, such as dry spells, intense wildfire, and poor air quality in Utah.

Objective 2: Quantify the tropical ocean impacts on prolonged drought conditions and subsequent natural disasters.

Objective 3: Integrate the obtained knowledge to connect the tropical ocean forcing, weather regimes, prolonged drought, and subsequent natural threats.

Objective 4: Establish a prototype of a drought forecasting system.

Objective 5: Disseminate the project outcomes.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

1) Major activity completed:

- Recruited one MS student co-advising with Prof. Wei Zhang.
- Submitted two journal articles in climate science.
- Submitted one proposal to NOAA competitive grant as a lead PI.
- Collected observation and model datasets to analyze hydroclimate predictability.
- Published two journal articles in climate science, and one article is a student corresponding authorship.
- Presented the project outcome in two workshops.

2) Specific objectives met:

- Identified how the large-scale atmospheric circulation relates to interannual variability of air quality, a sum of dry days, and wildfire size in the Northwestern United States.
- Differentiates the hydrological responses to the El Nino Southern Oscillation and the tropical inter-basin interaction.

3) Significant results achieved:

Based on the observational diagnostics, we found that the sea surface temperature contrast between the tropical Pacific and Atlantic is a better predictor for wet-dry conditions in Intermountain West and Southern Plains. This finding is applicable to developing an early warning of a multi-year drought. Using this finding, we have submitted a proposal to the NOAA funding opportunity: MAPP-NIDIS Science for the 21st Century Western U.S. Hydroclimate. Our proposal title is "Enhancing seasonal and multi-year hydroclimate predictability in the Western U.S. by capitalizing on inter-basin climate interaction".

4) Key impacts/accomplishments:

The published article entitled "The influence of tropical basin interactions on the 2020-2022 double-dip La Nina" has reached to more than 600 views and 100 downloads for three months from September to November at the journal webpage Frontiers.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

This project's main audiences during this period include students, scientists, water resource managers, policymakers, and funding agencies.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Initially, we planned to work on Objective 1: Identify weather regime impacts on drought-induced threats, such as dry spells, intense wildfires, and poor air quality in Utah, during this reporting period. However, the PI recognized that Objective 2 proposed in this project perfectly fit the NOAA funding opportunity announced in this summer. Therefore, the team switched to work on the Objective 2 to complete the preliminary analysis and then submitted the letter of intent to the NOAA funding opportunity. The funding manager encouraged us to submit the full proposal, and then the PI submitted the proposal on time.

Training and Professional Development:

The PI has mentored four graduate students (1 MS and 3 Ph.D. students) by organizing a weekly lab meeting and having a one-on-one meeting upon the student's request. The PI also organizes the monthly climate group meeting to foster students' professional development and encourage research exchange with our department's other climate group members. The PI also taught two courses (PSC 7900 Tropical Ocean-Atmosphere Interaction, PSC 6125 Climate Modeling, and Simulation) and two guest lectures for El Nino Southern Oscillation (PHYS 3880 Advanced Physics Laboratory, WATS 3000 Oceanography).

Dissemination:

The project outcomes were disseminated through two workshops: 1) Societally Relevant Multi-Year Climate Predictions Workshop and 2) Colorado River Climate and Hydrology Work Group. The audience of these workshops includes scientists, policymakers, and water resource managers. The PI also updated the web-based platform for multi-year forecasts of the Colorado River water supply on the Utah Climate Center webpage.

Publications:

Hasan, A. K. M. N., Chikamoto, Y., & McPhaden, M. J. (2022, September 20). The influence of tropical basin interactions on the 2020–2022 double-dip La Niña. *Frontiers in Climate*.

Presentations:

Chikamoto, Y. (Presenter & Author), Colorado River Climate and Hydrology Work Group, "Platform for drought early warning," Salt Lake City, Utah, USA. (November 16, 2022 - November 17, 2022)

Chikamoto, Y. (Presenter & Author), Societally-Relevant Multi-Year Climate Predictions Workshop, "Assessing multi-year predictability of the Colorado River water supply using a drift-free decadal climate prediction system," Boulder, Colorado, USA and Virtual. (March 28, 2022 - March 30, 2022)

Plan of Work:

During the next reporting period, we plan to focus on two objectives: 1) Identify weather regime impacts on drought-induced threats, such as dry spells, intense wildfire, and poor air quality in Utah; and 2) Quantify the tropical ocean impacts on prolonged drought conditions and subsequent natural disasters. Specifically, we will evaluate what weather regimes are highly related to the poor air quality in Utah and analyze the climate model experiments to quantify the tropical ocean impacts. We will also assess seasonal-to-multi-year predictability using dynamical climate models.



Species Diversity, Discovery, and Historical Biogeography of Nearctic and Neotropical Aphids

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Declines in insect abundances are being reported from all regions of the World, due to threats ranging from deforestation and urbanization to climate change. Coupled with overall losses in insect biodiversity, these trends are alarming, given the importance of insects as pollinators, prey, nutrient recyclers, and focal organisms in science and technology. Aphids (Hemiptera: Aphididae) are one of the most important groups of plant-feeding insects in agricultural and urban environments due to their physical damage by feeding and by acting as virus vectors. Presence of aphids on crop plants also can encourage visitation by invasive ants, which discourages pollination by bees. Introduced and invasive species (currently numbering close to 300 species) pose the greatest threats to agriculture and biodiversity. Problems will only intensify as a warming climate promotes more rapid insect reproduction and geographic range expansion. Ever-increasing global trade will increase the probability of aphid pests introduced to the U.S. In contrast to their pest status, aphids are also important resources for beneficial insects. Predatory insects may feed on aphids as a sole or partial resource; some pollinating insects tap the honeydew that aphids produce. To fully understand both biodiversity losses and threats by potentially invasive species, we must first quantify existing diversity and understand its history. This project will document species diversity in three groups of aphids—two groups including South American species and one group in eastern US—and describing new species as they are discovered. It further aims to understand the historical processes underlying species diversification. Studies documenting aphid diversity in South America are important for establishing what is native vs. adventive and potentially of agricultural concern. Many important crop pests from the north have established in this region, for example the cotton aphid, *Aphis gossypii*, the pea aphid, *Aphis fabae*, and the brown ambrosia aphid, *Uroleucon ambrosiae*. Cataloging the full diversity of aphids in South America would facilitate identification of potentially adventive or invasive species arriving in North America through commerce or other means. This project will advance scientific knowledge and potentially public welfare by contributing to our knowledge of biodiversity in under-sampled regions, as well as potential threats to biodiversity and agriculture.

Specific Objectives:

1. Amplify and sequence the mitochondrial COI “barcode” region to of Neotropical *Aphis* and *Uroleucon* aphid samples to identify known species and detect undescribed species.
2. For undescribed species, sequence additional genes and perform phylogenetic analyses to determine relationships between Neotropical, North American, and Palearctic species and infer their biogeographic history.
3. Identify haplotype groupings from mitochondrial data and determine geographic ranges of haplotype groups in *Hamamelistes* aphids. Infer putative undescribed species from haplotype groups.
4. For each *Hamamelistes* putative new species, analyze morphology to discover potential diagnostic characters. Describe new species and provide a comparative redescription of *H. spinosus* Shimer from the type locality.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Specific objectives and Accomplishments:

Objective 1: Amplify and sequence the mitochondrial COI “barcode” region of Neotropical Aphis and Uroleucon aphid samples to identify known species and detect undescribed species.

We amplified and sequenced COI barcode loci from ~20 *Uroleucon* samples. We combined forward and reverse reads to generate contigs and exported consensus sequences to add to our existing data set, to confirm known species.

We amplified, sequenced, and analyzed COI and COII genes from samples of *Blanchardaphis* to determine species limits.

Objective 2: For undescribed species, sequence additional genes and perform phylogenetic analyses to determine relationships between Neotropical, North American, and Palearctic species and infer their biogeographic history.
We amplified and sequenced COII loci from ~20 Uroleucon samples. We combined forward and reverse reads to generate contigs and exported consensus sequences to add to our existing data set.

Objective 3: Identify haplotype groupings from mitochondrial data and determine geographic ranges of haplotype groups in Hamamelistes aphids. Infer putative undescribed species from haplotype groups.
We obtained samples of Hamamelistes aphids from a collaborator in the eastern US, and extracted genomic DNA in preparation for COI PCR amplification and sequencing.

Objective 4: For each Hamamelistes putative new species, analyze morphology to discover potential diagnostic characters. Describe new species and provide a comparative redescription of H. spinosus Shimer from the type locality.
No activity yet.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Other insect systematists around the World, researchers working on historical biogeography of insects and systematics of aphid parasitoids and predators, applied researchers working on biological control of aphids, and basic and applied researchers with needs for accurate identification of aphids.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None.

Training and Professional Development:

This project provided training for MS student Gavin Munson and undergraduate Audrey Mullens in molecular biology laboratory skills and computer analysis, bioinformatics, and systematics. This project is also helping to support the master's research of Mr. Munson. Specific skills gained by the graduate and undergraduate students included purifying high quality genomic DNA and RNA, PCR gene amplification, purifying PCR products, compiling/correcting contigs and aligning sequences, designing primers for PCR, and using GenBank and other bioinformatics resources.

Dissemination:

Dissemination of results are through publications in peer-reviewed journals. This project also provided opportunities for Native American students from the USU Blanding campus to learn about insect biology and identification, and participate in field and bench research in the PI's laboratory.

Products:

Other Products:

Physical Collections - Collections of aphids from eastern North America and South America.

Data and Research Material - DNA sequences of aphids from eastern North America and South America.

Plan of Work:

For Objectives 1 and 2, we will focus on amplifying and sequencing COI, COII, and EF1a genes to fill in the data set for the Uroleucon historical biogeography study. We will also extract, amplify and sequence any new Uroleucon or Aphis samples that our collaborators in Spain and Argentina send us.

For Objective 3 we will amplify and sequence COI genes for the new Hamamelistes aphid samples sent by our collaborator. We will add these to the existing data set compiled from GenBank, and perform a phylogenetic analysis to discriminate putative species and determine geographic ranges of well-supported lineages.

For Objective 4 we will slide mount and analyze alate and fundatrix generations of samples from H. spinosus and H. blackmani aphids, to determine if there exist discriminatory characters for any distinctive lineages emerging from the phylogenetic analysis, above.

Combinations of Water, Crop, and Soil Management to Enhance Water Optimization

Project Director

Matt Yost

Organization

Utah State University

Accession Number

7002876



Combinations of Water, Crop, and Soil Management to Enhance Water Optimization

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

This project will continue to address critical needs related to conserving and optimizing water use in irrigated agriculture. It will include long-term, replicated evaluations of several combinations of high potential solutions for conserving water. Solutions of interest include: i) improving irrigation efficiency with advanced equipment and scheduling; ii) genetic advances in the drought tolerance of crops; and iii) improving the ability of the soil to retain water by using less tillage and utilizing cover crops. Concurrently focusing on many of these factors in combination will provide effective solutions for water scarcity and create sustainable pathways for future agricultural systems.

Objectives:

1. Identify combinations of water, crop, and soil management practices (irrigation system, precision irrigation, deficit irrigation, coupled with crop type, crop genetics, cover crops, soil wetting agents, and tillage) with the greatest ability to optimize crop production, crop profit, soil health, and water use.
2. Deliver dynamic educational products and training on water optimization through Extension and coordinated outreach to increase awareness and adoption of proven water optimization practices.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: Identify combinations of water, crop, and soil management practices (irrigation system, precision irrigation, deficit irrigation, coupled with crop type, crop genetics, cover crops, soil wetting agents, and tillage) with the greatest ability to optimize crop production, crop profit, soil health, and water use.

The goals and aims of this objective were to establish and maintain three long-term irrigation research fields in Utah where multiple water conservation practices can be investigated and compare the water use efficiency, productivity, and economics of various combinations of water conservation practices to identify the most ideal combinations. All three sites are fully established and we have published over 15 extension articles on results from the first three growing seasons of data. Results have also been presented to over 1,000 stakeholders in various formats in Utah, the west, and in international conferences. Two graduate students were trained and have or will shortly complete their Master's thesis.

Accomplishments included collection of data on how 16 irrigation and 5 crop/soil treatments influenced yield and water use of corn, alfalfa, small grains, and alternative crops (safflower, teff, hemp). Hosting a virtual and face-to-face field days with

over 300 participants. Disseminating results in several fact sheets, press articles, and presentations at local, regional, and international meetings. Training of several graduate and undergraduate students. Securing additional grants to support expansions of this research.

The information from this study about water optimization practices has and will be especially useful in guiding water conservation planning at the farm level, which would in turn have large impacts on planning efforts at watershed and basin levels. It will also help irrigators prepare to effectively participate in water demand and banking programs, should they be developed and necessary. One example is an irrigation investment calculator that we built (in part) using data collected from this study. This tool guides investments in water optimization practices.

Objective 2. Deliver dynamic educational products and training on water optimization through Extension and coordinated outreach to increase awareness and adoption of proven water optimization practices.

The results of this project were disseminated in many ways through various Extension channels. We posted information and results on our social media accounts (USUcrops) that have nearly 1,500 followers. We also shared the results on our USUcrop website that gets several thousand visits each year. This included a virtual crop school in January 2022 with over 200 participants. We recorded all the presentations and made them available as individual YouTube videos. There have been over 1,000 views of the crop school presentations in the last year. Pesticide use credits (required for pesticide applicators) were offered. We issued a total of 80 credits. Attendees joined from almost every county in Utah, along with some from neighboring states.

Results of the research objectives were also presented at various in-person crop schools and field days where we educated farmers, water managers, state agency personnel, and various other stakeholders. In addition to presenting results at various events, we also disseminating results in several fact sheets, press articles, and presentations at regional, and international conferences.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences include Agricultural producers, Extension personnel, water users, water managers, government agencies, agribusiness personnel, and other scientists.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Both objectives were completed without major shifts from the original plan. Changes that have occurred have been additional measurements and research sites due to interest of graduate students and stakeholders.

Training and Professional Development:

The project provided a total of five undergraduate students (Megan Baker, Naomi Boren, Josh Tano, Chase Harris, LuRee Johnson) and five graduate students (Tina Sullivan, Jonno Holt, Dakota Boren, Elisa Flint, Britta Schumacher) and one postdoc (Brad Crookston) and one visiting scholar (Ngoni Mufute) with training in field plot establishment and maintenance, research methods, and data collection and processing techniques.

Dissemination:

Dissemination has mainly consisted of presentations at national and regional conferences, field days, and Extension meetings. My research team gave over 10 presentations at national and regional conferences. Work was also presented over 50 times at Extension events in several Utah counties and in several field tours of my research plots with small groups of Extension

personnel, industry representatives, and agricultural producers. The research from this project was also presented during several in-service events to train Extension agents and other industry personnel. Six journal articles were accepted on this work, eight fact sheets, and three farm press and other articles.

Plan of Work:

For objective 1, analysis of 2022 data is being prepared for publication in extension articles, farm press articles, and professional publications. Ongoing and additional crop production and water use measurements will be collected in three long-term water optimization trials and in several ongoing and new on-farm trials in 2023. For objective 2, results will continue to be presented at conferences and winter crop school meetings, summer field days and be published in press, trade journal, and research journals.

Food Chain Transfer of Toxic Trace Elements in Urban Agriculture

Project Director

P Grossl

Organization

Utah State University

Accession Number

7002873



Food Chain Transfer of Toxic Trace Elements in Urban Agriculture

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall objective of this project is to develop soil tests that accurately predict if lead (Pb) and arsenic (As), and other trace elements, are taken-up by produce grown in urban agricultural systems and potentially threaten human health, and if so, provide best management practices that will mitigate their bioavailability.

Specific objectives are: 1) To determine the Pb and As levels of soil and plant samples collected from community garden sites located throughout urban areas along the Wasatch Front. 2) Develop bioavailability soil tests for Pb and As using sequential extraction procedures, and 3) Based on the results from objectives 1 and 2, develop guidelines for urban agriculturists that will mitigate Pb and As bioavailability.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Urban soil contamination has become an increasing concern within residential developments and with the expansion of urban agriculture, which has rapidly grown across the United States. In Salt Lake County, Utah, there are 39 community gardens and urban farms, with more currently in development, though limited data exist regarding trace element or hydrocarbon contamination in these soils. The purpose of this study was to conduct an urban soil survey in Salt Lake County to screen soils in community gardens and urban farms for common contaminants including trace elements, mainly total lead and arsenic, along with organic contaminants: petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and volatile organic carbons. Site selection included an emphasis on sites serving at least nine families, and those with a greater potential for soil contamination from historical land use, proximity to industrial sites, and heavy traffic. Measured soil test concentrations were compared to EPA regional screening levels (RSL) and nationwide background levels. Lead concentrations ranged from 14.8 to 516 mg kg⁻¹, with a mean concentration of 91.8 mg kg⁻¹, while arsenic ranged 2.83 to 39.3 mg kg⁻¹ (mean of 11.8 mg kg⁻¹), all of which exceeded the EPA RSL of 0.68 mg kg⁻¹. Benzo (A) pyrene was the primary hydrocarbon contaminant of concern, and concentrations that were above detectable limits ranged from 0.01 to 0.44 mg kg⁻¹, with a mean concentration of 0.09 mg kg⁻¹. By determining the baseline degree of soil contamination in key urban agricultural sites in Utah's most populated county, local screening levels were developed to soil management plans for producers.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience is urban farming community groups to help them analyze and become aware of potential health risks associated with metal contaminated soils and how to manage them.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

We have been involved in workshops on soil reclamation and soil health for urban community gardens and US Golf Association (USGA).

Dissemination:

Two extension fact sheets were produced. One on trace element contaminants is published and the other on polyaromatic hydrocarbons is currently under review. Also, two journal articles are currently in preparation.

Products:**Other Products:**

Data and Research Materials Two extension fact sheets were produced. One on trace element contaminants is published and the other on polyaromatic hydrocarbons is currently under review.

Plan of Work:

Plan of Work for 2023

- Data collection and contaminant analysis to assess urban soil health.
- Develop reclamation guide lines for contaminated soil restoration.

[Quantifying the distributed effect of wildfire smoke on waterbodies in the Western U.S.](#)

Project Director

Janice Brahney

Organization

Utah State University

Accession Number

7002879

**Quantifying the distributed effect of wildfire smoke on waterbodies in the Western U.S.**

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The project will evaluate the impact of dispersed wildfire smoke on water bodies through the following objectives,

Objective 1: Quantify the deposition rate and composition of charcoal and ash deposited across the western United States. We hypothesize that landcover types burned will influence the nutrient bioavailability and metal content of the deposited material.

Objective 2: Evaluate the effect of pervasive smoke cover and deposition on aquatic ecosystems. We predict that nutrient-rich ash deposition will stimulate primary production and alter species composition, while metal-enriched deposition will suppress production. We further hypothesize that heavy smoke cover will suppress production, while light smoke cover will restructure phytoplankton communities through the attenuation of UV radiation and the additional scattering of photosynthetically active radiation.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: Quantify the deposition rate and composition of charcoal and ash deposited across the western United States.

Progress towards objective one includes several activities. The first is the collection of dry atmospheric deposition across the western US to evaluate charcoal concentration, size, and effects on deposition chemistry. Samples have been collected and are archived, awaiting analyses.

Second, we requested wet deposition filters from the NADP from 7 sites that typically see fire activity through the summer period. Here our intention is to evaluate charcoal deposition rates through periods of fire and evaluate the effect on precipitation chemistry. These samples are archived and awaiting analysis.

Finally, with collaborators at the University of Nevada Reno and the University of California, Davis, we collected ash deposition around lake Tahoe during the Caldor Fire. Ash collected could be described as brown ash, or less pyrolyzed ash, and gray ash. I analyzed the two contrasting ash types for water-leachable, oxidizable, and residual nutrients and metals.

Results

Not all ash is created equal. As with the rate of ash fall around the lake, the composition of the ash that fell was highly variable in space and time. The composition of the ash was related to the degree to which it had burned where particles still identifiable as burned vegetation, dominantly brown in color, contained higher concentrations of leachable nutrients. Whereas ash that was gray in color and fine-grained contained lower concentrations of bioavailable nutrients. Interestingly, the brown ash fell further from the fire at the northern and western portions of the lake. Despite the lower concentrations of bioavailable nutrients in the ash that fell to the south, five times the mass of ash fell in the region leading to overall greater amounts of bioavailable nutrient deposition. Both the quantity and quality of ash are expected to influence algal production by providing key limiting nutrients, including phosphorus (P), nitrogen (N), and micronutrients.

As noted above, the less pyrolyzed ash was higher quality in that greater amounts of nutrients (P, N, Mg, Na, Cu, Fe, Mn, and Zn) were leached as compared to the more pyrolyzed ash in both the water-extractable and oxidizable fraction. The more pyrolyzed ash contained greater concentrations of Ca and K and bound (unavailable)-P, likely due to the formation of carbonates during pyrolyzation. The less-pyrolyzed ash also contained higher concentrations of toxicants, such as As, Cd, Cr, Ni, and Pb, though the water-extractable concentrations remained low. Site-specific analyses revealed a high variability in ash quality and deposition rates, though in general higher quality but lower amounts of ash fell to the northern and western areas of the lake while greater amounts of more pyrolyzed ash fell to the southeast. This pattern led to greater deposition rates of oxidizable N and P in the south and east despite the lower quality composition.

Objective 2: Evaluate the effect of pervasive smoke cover and deposition on aquatic ecosystems.

With collaborators at the University of Reno and the University of California, we conducted bioassay experiments using ash collected from objective 1.

Results

The experiments conducted indicated that both the quality of the ash that fell as well as the altered light conditions have the potential to increase algal production. In addition, we found that the initial condition of the lake, including the lake nutrient trophic state and starting algal composition, will control the degree to which algae respond. In all experiments, the simulated

reduced light environment amplified the algal response to the ash additions. The complexity of the response suggests that more experimental conditions are required to disentangle the relative role of ash composition (including micronutrient and toxin concentrations), microbial respiration, and algal production.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Land managers
Academic audiences

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No changes or problems

Training and Professional Development:

This research provided several opportunities for undergraduates, graduates, and technicians to gain laboratory experience. Technicians Audree Provard, Lauren Jones, and Camilla Moses as well as one undergraduate, Mackenzie Bingham, have assisted with sample processing and analyses. Graduate students Jiahao Wen and Mark Devey also assisted with the chemical analyses of the deposited ash samples. The latter included some methods development.

Dissemination:

The findings of the Caldor Fire research have been disseminated to the Tahoe Reno Planning Agency and a manuscript for publication in an academic journal is being written.

Products:

Other Products:

Physical Collections - We have collected atmospheric deposition samples, which are archived for charcoal analyses.

Plan of Work:

During the next reporting cycle we aim to,

- Submit research grants for funding to support ongoing work
- Analyse wet and dry deposited materials for ash concentrations, size, and shape characteristics
- Evaluate the role of ash concentration on precipitation chemistry
- In collaboration with a colleague at the University of Utah, Dr. Alexandra Ponnette-Gonzalez, examine the role of vegetation chemistry on the composition of ash and precipitation chemistry



Enhancing Functional Diversity in Western Rangelands: Landscape Interventions and the Design of Smart Foodscapes

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The long-term goal of this project is to improve the economic and environmental sustainability of beef production systems in the western U.S. through the establishment in the landscape of “islands” of legumes and forbs of multifunctional diversity. The work entails developing smart foodscapes after screening legumes and forbs for synergisms and complementarities *in silico* (Objective 1) and *in vitro* (Objective 2), that will be strategically deployed in “islands” or patches across the landscape and tested for their effects on beef cattle performance, behavior, health and welfare (Objective 3) and environmental impact (Objective 4).

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The long-term goal of this project is to improve the economic and environmental sustainability of beef production systems in the western U.S. through the establishment of islands of multifunctional diversity in the landscape. Since July 2022, significant progress was achieved on Objectives 1 & 3.

Objective 1. The aim of this work was to simulate the effect of different grazing management practices by contrasting frequency (once a week, fortnight, and month) and dietary proportions (5, 10, 15 and 20%) of tannin-containing legumes (either sainfoin or birdsfoot trefoil) allocation to the virtual cow MINDY grazing a basal diet of grass in grass-dominated rangeland. Outputs of the model were animal performance and environmental impact in terms of methane production and urinary N excretion. MINDY is a deterministic, mechanistic, and dynamic model of a dairy cow representing diurnal patterns of ingestion, digestion, excretion, metabolism, and production based on explicit relationships among direct (ingestion, digestion and metabolism) and indirect (feeding environment) controls of motivation to feed. MINDY parameters were initialized as a pregnant beef cow for this project. Twenty-five simulation scenarios (treatments) were established as a product of a factorial arrangement between grazing frequency (weekly, fortnightly, and monthly) and dietary proportions (5, 10, 15, and 20% of total forage allocation) of either sainfoin or birdsfoot trefoil allocation to MINDY. The bulk of the diet was represented by grass (smooth brome grass). Each simulation or treatment was run for 70 days, which included 10 days of ‘model adaptation/stabilization’, and the last days of data collection. Preliminary results show that monthly frequencies of legume allocation and 15 to 20% proportion of legumes in the diet have a positive effect on production parameters with the lowest levels of environmental impacts in terms of methane emissions intensity and urinary N excretion.

Objective 3. The team developed and tested a location tool for selecting the most appropriate locations for establishing nine 30x40 m legume/forb plots (“islands of diversity”) and applied it to the experimental pasture: 55 acres of smooth brome grass pasture monoculture, located at the UAES Richmond Research Farm. Greenness at this pasture was determined using GIS for the last 7 years using Landsat imagery, retrieving NDVI data. Since greenness is a function of NDVI, pixels with a 7-year average greenness above the average of the pasture served as candidate locations for establishing the islands of diversity. A protocol was also developed to identify drinking water points to be as distant from the islands of diversity as possible. Selected 30x40 m plots were sprayed with a general herbicide to eliminate all vegetation May 12 and August 17, 2022. All plots were then seeded November 17 in five parallel strips (8 x 30 m each) with: 1-alfalfa, 2-birdsfoot trefoil, 3-sainfoin, 4-small burnet and 5-forage kochia such that cows could select among these species. A watering system for the cows was also developed during the period. Half of the perimeter of the 55-acre pasture was un-fenced and thus it was fenced with permanent fence on August 31. A semi-permanent electric fence was also built at the center to divide the pasture into 2 equal blocks. Temporary electric fence, perpendicular to this fence will divide the pasture into 6 paddocks.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Livestock producers, extension personnel, land managers, graduate and undergraduate students, conservation agents and professionals, veterinary medicine professionals.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Inflation has been quite significant and problematic. Cost of materials and supplies have increased significantly. Budgeted hourly rates for technical help are not commensurate with the current costs of living.

Training and Professional Development:

A new PhD student was recruited, Iddy Bashir, and he started his program in August. He received the prestigious Quinney Doctoral Fellowship from USU to pursue his studies working on the project.

A technician, Jacob Poulsen was trained in pasture research and establishment and watering systems for cows.

Project PI conducted three lectures for students that described theory and applications of the current project listed below.

Villalba, J.J. 2021. Animal welfare in grazing systems. Virtual Workshop for the “MS in Animal Welfare 2021-2022,” Autonomous University of Barcelona, Spain, November 3, 2021.

Villalba, J.J. 2022. Grazing and learning in Ruminants. The lecture was given in the context of the graduate-level course: Pasture Systems. Universidad de Buenos Aires, Argentina, August 26, 2022.

Villalba, J.J. 2022. Foraging Behavior in Ruminants. Lecture in the context of the graduate-level course: Ruminant Production Systems. Universidad de la República, Uruguay, October 6, 2022.

Dissemination:

The project created a website to disseminate information: <https://www.usu.edu/smart-foodscapes/index>.

The project leadership team worked on a short video about the project for the general public, currently in production phase. This video will be placed on the project website, shared on social media, provided to USDA leaders, and shared using other means.

Presentations:

J. Villalba, D. Dahlgren, E. Thacker, & K. Trundle. USU WILD Department Seminar on February 16, 2022, updating the department, S.J. Quinney College of Natural Resources, and others within the USU community on the SFS project. We gave a broad overview of the project plans and objectives.

Villalba, J.J. 2022. Using Smart Foodscapes to Enhance the Sustainability of Western Rangelands. Presentation at The Sustainable Grazing Institute: merging the art and science of management intensive grazing. June 7, 2022, Kaysville, UT.

Villalba, J.J. 2022. Platform Speaker for Pastures and Forages: Smart Foodscapes: Developing Functional Landscapes to Enhance the Sustainability Livestock Production Systems. Invited presentation at the American Society of Animal Science (ASAS), and the Canadian Society of Animal Science (CSAS) 2022 Joint Annual Meeting. June 26-30, 2022.

Villalba, J.J. 2022. Using Smart Foodscapes to Enhance the Sustainability of Western Rangelands. Presentation at the 2022 NCCC31 Eco physiological Aspects of Forage Management Annual Meeting June 15-17, University of Wyoming (UW), Laramie, WY.

Villalba, J., ANIMAL WELFARE MASTERS PROGRAM - AUTONOMOUS UNIVERSITY OF BARCELONA, "Animal welfare in grazing systems," USDA-NIFA, Logan, Utah. (October 13, 2022)

Ortíz-Domínguez, G. (Presenter & Author), González-Pech, P. (Author Only), Sandoval-Castro, C. A. (Author Only), Ventura-Cordero, J. (Author Only), Villalba, J. (Author Only), Torres-Acosta, J. F., 3er Congreso Universitario en Innovación y Sostenibilidad Agroalimentaria (CUISA), "Comparación del conteo de huevos de nematodos gastrointestinales de caprinos adultos en relación con la hora del día en condiciones tropicales de pastoreo." (September 15, 2022 - September 16, 2022)

Ortíz-Domínguez, G. (Presenter & Author), Sandoval-Castro, C. A. (Author Only), González-Pech, P. (Author Only), Villalba, J. (Author Only), Torres-Acosta, J. F., Ventura-Cordero, J. (Author Only), 3er Congreso Universitario en Innovación y Sostenibilidad Agroalimentaria (CUISA), "Variables conductuales y cargas parasitarias de caprinos en el trópico: independencia en los muestreos." (September 15, 2022 - September 16, 2022)

Publications:

Bleke, C., Geese, E., Roberts, S., & Villalba, J. (2022, November 08). Seasonal shifts in pronghorn antelope (*Antilocapra americana*) diets under a new lens: Examining diet composition using a molecular technique. *PLOS1*.

MacAdam, J. W., Pitcher, L. R., Bolleta, A. I., Guevara, R., Beauchemin, K., Dai, X., & Villalba, J. (2022, January 25). Increased Nitrogen Retention and Reduced Methane Emissions of Beef Cattle Grazing Legume vs. Grass Irrigated Pastures in the Mountain West USA. *Agronomy*, 12(2), 304.

Ortíz-Domínguez, G., Sandoval-Castro, C. A., Torres-Acosta, J. F., Ventura-Cordero, J., Villalba, J., & González-Pech, P. G. Time-varying path in nutritional, productive variables, and their relationship with gastrointestinal nematode infection level in a tropical farm context. *Animals*.

Pedernera, M., Vulliez, A., & Villalba, J. (2022, January 01). The influence of prior experience on food preference by sheep exposed to unfamiliar feeds and flavors. *Applied Animal behaviour Science*, 246, 105530.

Provenza, F. D., Villalba, J., & Kleppel, G. (2021). Editorial: Livestock Production and the Functioning of Agricultural Ecosystems, Volume II. *To appear in Frontiers in Sustainable Food Systems*.

Villalba, J., MacAdam, J. W., Van Vliet, S., & Provenza, F. D. Integrating Plant Secondary Metabolites and Foraging Behavior to Enhance Animal Health in Beef Production Systems. *International Grassland Congress Proceedings*.

Villalba, J. (2022, September). Smart Foodscapes: Developing Functional Landscapes to Enhance the Sustainability Livestock Production Systems. *Journal of Animal Science*, 100(Supplement_3), 89-90.

Plan of Work:

Objective 1. Continue with analyses and interpretation of model outputs.

Objective 2. Preparation of forages and samples for *in vitro* studies.

Objective 3. Weed control and evaluation of species of legumes and forbs planted in November. Familiarize cows with methane collection equipment. Recruit one MS student for grazing studies.

Low Water Use Landscape Plants for Water Efficient Landscaping in the Intermountain West

Project Director

Youping Sun

Organization

Utah State University

Accession Number

7002877



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overarching objectives of this project are:

- 1) to enhance the understanding of whole-plant responses of landscape plants to water stresses in urban landscapes,
- 2) to provide practical recommendations of low water-use plants for water-efficient landscaping.

These broad objectives will be achieved through the following sub-objectives:

- A. Evaluate the effects of deficit irrigation on landscape plants that are commonly used in Utah and the Intermountain West,
- B. Evaluate the effects of substrate moisture levels on landscape plants that are commonly used in Utah and the Intermountain West,
- C. Participate in field days hosted by the Utah State University's Center for Water-Efficient Landscaping to share project results and showcase field trial plots.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective A: Evaluate the effects of deficit irrigation on landscape plants in field conditions.

A-I: Twenty-six ornamental grass and grass-like species/cultivars were planted in 2018 in Utah Agricultural Experiment Station's (UAES's) Greenville Research Farm following a randomized complete block design. Plant growth and performance data were recorded in 2019, 2020, and 2021, in order to select suitable ornamental grasses for landscape use in Utah and the Intermountain West, one of the driest and fastest growing regions in the United States. Number of tillers and dry weight data were collected in Spring 2022. Dry samples of selected species [*Carex vulpinoidea* (fox sedge), *Juncus effuses* (common rush), *Leymus arenarius* (sand ryegrass), *Pennisetum alopecuroides* (fountain grass), *Eragrostis spectabilis* (purple love grass), *Cymbopogon citratus* (West Indian lemon grass), *Calamagrostis × acutiflora* (feather reed grass)] from this field trial study and other greenhouse studies were grounded for pyrolysis at the Utah Science Technology and Research Bioenergy Center.

A-II: A field trial plot with 400 plugs of *Calamagrostis × acutiflora* 'Karl Foerster' ('Karl Foerster' feather reed grass) was established in UAES's Greenville Research Farm in Fall 2021. Deficit irrigation treatments, 80%, 60%, 40%, 20%, 0% reference evapotranspiration rate (ET_o), were applied in summer 2022. Plant growth and soil moisture data were recorded to evaluate their field performance under deficit irrigation.

A-III: Thirty newly developed landscape plant species/cultivars (720 plants total) have been transplanted to UAES's Greenville Research Farm. For the first field trial plot established in May 2021, 456 plants (19 species/cultivars) were irrigated at 80% of reference evapotranspiration (ET_o) throughout summer 2021 for establishment. These plants were evaluated with three deficit irrigation treatments representing 80%, 50%, and 20% of ET_o in 2022. Visual quality and plant growth and physiology data were collected. For the second plot established in May 2022, 264 plants (11 species/cultivars) were irrigated at 80% of ET_o throughout summer 2022 for establishment. These plants will be evaluated with three deficit irrigation treatments in 2023. Low water use landscape plants will be identified for use in Utah and the Intermountain West.

A-IV: Grafted pinyon pines were transplanted to Hurricane Valley Fruit Farms and UAES's Blue Creek Research Farm in May-June 2022 and will be evaluated in the years to come (8-10 years).

A-V: Twenty-three pomegranate cultivars, propagated via cuttings from U.S. National Plant Germplasm System, were planted in November 2022 in M&I Farm and Greenhouse, Hurricane, UT, following a randomized complete block design. This field trial plot, along with a field trial plot established in Hurricane Valley Fruit Farms, Hurricane, UT, in 2018, will be used to identify superior pomegranate cultivars that are resistant to fruit split, sunburn, cold temperatures, diseases, and pests for edible landscape use.

Objective B: Evaluate the effects of substrate volumetric water contents on landscape plants in greenhouse conditions

B-I: A greenhouse experiment was conducted to evaluate the effects of substrate volumetric water contents on the growth and development of *Penstemon barbatus* 'Novapenblu' (rock candy blue penstemon), *P. digitalis* 'TNPENDB' (dakota™ burgundy beardtongue), *P. ×mexicali* 'P007S' (pikes peak purple® penstemon), and *P. strictus* (Rocky Mountain penstemon) in November 2021 – March 2022. This research helped understand the morphological and physiological responses of landscape plants to varying substrate volumetric water contents maintained using a sensor-controlled automatic irrigation system in a controlled environment.

B-II: A greenhouse experiment was conducted to evaluate the effects of substrate volumetric water contents on the growth and development of *Hibiscus syriacus* 'JWNWOOD4' (pink chiffon® rose of sharon), *Rosa* 'Meibenhino' (petite knockout® rose), *Rosmarinus officinalis* 'Arp' ('Arp' rosemary), *Vitex agnus-castus* 'SMVACBD' (blue diddley® chastetree) in September – November 2022. This research helps understand the morphological and physiological responses of landscape plants to varying substrate volumetric water contents maintained using a sensor-controlled automatic irrigation system in a controlled environment.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Homeowners
Landscape Professionals
Nursery Growers

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

- This project will enhance our understanding of whole-plant responses to deficit irrigation while identifying and selecting drought-resilient landscape plants for water conservation.
- Growers will benefit from having access to low-water-use plants for sustainable production, while the public will have the opportunity to incorporate these plants into their own landscapes.
- The information generated from this project will contribute to water conservation efforts and improved environmental stewardship by fostering public acceptance of adapted, drought-resilient plants.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

Annual Conference of American Society for Horticultural Science, Chicago, IL, 30 July - 3 August 2022.

Advancing Mentoring Workshop, USU's College of Agriculture and Applied Sciences, Logan, UT, 1:00-3:30, 19 and 26, January 2022. Organizers and Presenters: Drs. Abby D. Benninghoff, Brent Chamberlain, Heloisa Rutigliano, and Elizabeth Vargis.

Teaching Documentation Workshop, USU's Provost's Office, Logan, UT, 8:00-4:30, 10-13 May 2022. Mentor: Dr. Cathy Ferrand Bullock, Department of Journalism and Communication, USU, Logan, UT.

Dissemination:

Two peer-reviewed papers were (will be) published to disseminate research results to scientific community.

1. Chen, J., Y. Sun, K. Kopp, L. Oki, S.B. Jones, and L. Hipps. 2022. Effects of water availability on leaf trichome density and plant growth and development of *Shepherdia ×utahensis* 'Torrey'. *Frontiers in Plant Science*. 13:1-14.
2. Chen, J., Y. Sun, K. Kopp, L. Oki, S.B. Jones, and L. Hipps. 2022. Physiological and canopy temperature responses to drought of four penstemon species. Accepted by *HortScience* on December 7, 2022.

Three conference abstracts were published to disseminate research results to scientific community.

1. Chen, J., Y. Sun, and K. Kopp. 2022. Detecting drought stress of penstemons using infrared thermal imaging. *HortScience* 57(9): S58.
2. Chen, J., J. Mathews, A. Paudel, and Y. Sun. 2022. Field trials of 26 ornamental grasses and grass-like plants. *HortScience* 57(9): S129.
3. Sun, Y. 2022. Sustainable landscape horticulture program. *HortScience* 57(9): S175-176.

Twelve presentations were made to disseminate research results to academic community and county agents.

1. Chen, J. and Sun, Y. (2022, October 28). An evaluation of homeowner preference to native landscape plants under deficit irrigation. Presentation at WERA-1013: Intermountain Regional Evaluation and Introduction of Native Plants Annual Meeting. Virtual. (20 faculty members from 15 universities).
2. Chen, J. and Sun, Y. (2022, October 21). USU Climate Ready Landscape Plants Trial. Field Day. Utah Agricultural Experiment Station's Greenville Research Farm, North Logan, UT. 20 participants (undergraduate students from Brigham Young University-Idaho, Rexburg, ID).
3. Chen, J. and Sun, Y. (2022, October 18). USU Climate Ready Landscape Plants Trial. Field Day. Utah Agricultural Experiment Station's Greenville Research Farm, North Logan, UT. 10 participants (students and teachers from InTech Collegiate Academy, Logan, UT).
4. Chen, J. and Sun, Y. (2022, September 13). USU Climate Ready Landscape Plants Trial. Utah State University's Center for Water-Efficient Landscaping (CWEL) Virtual Field Day, CWEL, Logan, UT. 62 participants.
5. Chen, J. and Sun, Y. (2022, August 17). USU Climate Ready Landscape Open House. Utah Agricultural Experiment Station's Greenville Research Farm, North Logan, UT. 47 participants.
6. Chen, J. and Sun, Y. (2022, June 22). USU Climate Ready Landscape Plant Trial. Field Day. Utah Agricultural Experiment Station's Greenville Research Farm, North Logan, UT. 15 participants (summer citizens).
7. Chen, J. and Sun, Y. (2022, June 18). USU Climate Ready Landscape Plants Trial. Field Day. Utah Agricultural Experiment Station's Greenville Research Farm, North Logan, UT. 6 participants (Master Gardeners led by Extension Educator at the University of Idaho).
8. Chen, J., Mathews, J., Paudel, A., and Sun, Y. (2022, August 2). Field trials of 26 ornamental grasses and grass-like plants. American Society for Horticultural Science (ASHS) Annual Conference, Chicago, IL.
9. Sun, Y. (2022, August 2). Sustainable landscape horticulture program, American Society for Horticultural Science (ASHS) Annual Conference, Chicago, IL.
10. Chen, J., Sun, Y., and Kopp, K. (2022, July 31). Detecting drought stress of penstemons using infrared thermal imaging. American Society for Horticultural Science (ASHS) Annual Conference, Chicago, IL.
11. Chen, J. (2022, July 31). Using thermal imaging to detect plant water status. American Society for Horticultural Science (ASHS) Annual Conference, Chicago, IL.
12. Sun, Y., R. Wyssalucy, and B. Scow. (2022, March 3). Establishing pinyon pine orchards for nut production on marginal lands. 2022 Extension Annual Conference, Thanksgiving Point, Lehi, UT.

Other Products:

Audio or Video - A video "Landscapes of Change: Climate Ready Landscape Plants – Part 2" were produced by Pacific Horticulture to showcase the project funded by 2019 USDA Agricultural Marketing Service Specialty Crop Multi State Program.

<https://www.pacifichorticulture.org/videos/landscapes-of-change-climate-ready-landscape-plants-part-2/>

Plan of Work:

1. One manuscript "Responses of four landscape species to varying substrate volumetric water contents" is in preparation for HortScience.
2. One manuscript "Field performance of landscape plants under deficit irrigation" is in preparation for HortScience.
3. Evaluate eleven landscape plant species/cultivars with three deficit irrigation treatments in 2023.
4. Collect plant growth and soil moisture data for *Calamagrostis ×acutiflora* 'Karl Foerster' ('Karl Foerster' feather reed grass) with deficit irrigation treatments including 80%, 60%, 40%, 20%, 0% reference evapotranspiration rate (ET₀).
5. Evaluate field performance of grafted pinyon pines in Hurricane Valley Fruit Farms and UAES's Blue Creek Research Farm in the years to come (8-10 years).
6. Maintain the pomegranate plot in M&I Farm and Greenhouse, Hurricane, UT, and collect data for the plot in Hurricane Valley Fruit Farms, Hurricane, UT.

Climate change and ecosystem services: reducing critical uncertainties from ecosystem acclimation

Project Director

P Adler

Organization

Utah State University

Accession Number

7002823



Climate change and ecosystem services: reducing critical uncertainties from ecosystem acclimation

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective 1. Characterize the time-scales of acclimation processes and their relative impacts on ecosystem services.

Even crude estimates of acclimation rates and their impacts on ecosystem services will greatly reduce uncertainty in the future trajectory of ecosystem services (Fig. 1B). I will convene a working group of experts on paleoecology, long-term observational studies, experiments, and simulation models to synthesize relevant information from the published literature.

Objective 2. Test the hypothesis that lags in ecosystem acclimation are already eroding ecosystem services.

I will pursue this objective by analyzing existing long-term data sets, like the forage production data set of Felton et al. (in review). If we can detect the signature of acclimation lags in long-term data on ecosystem services, we can then explore the causes of these lags. Understanding why some systems are more prone to acclimation lags and loss of ecosystem services than others would help link our basic research with climate adaptation management frameworks like "resist-accept-direct".

Objective 3. Will evolutionary selection and dispersal shape an important species' response to climate change?

The invasive annual grass *Bromus tectorum* (cheatgrass) is a primary threat to sagebrush steppe ecosystems. How climate change will alter the ecosystem service of invasion resistance is unknown. Cheatgrass populations in North America exhibit substantial genetic variation. Furthermore, some population may be locally adapted: genotypes from lower elevations

germinate and develop quickly while genotypes from cooler sites have slower life history. If populations are locally adapted, then genotypes currently found in cold sites might respond negatively to warming in the near-term, but if acclimation processes eventually lead to replacement by warm-adapted genotypes, then warming would accelerate population growth. My collaborators and I will use existing common garden experiments to study how acclimation lags caused by evolutionary selection and dispersal could influence cheatgrass's response to climate change.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The project has two objectives:

Objective 1. Characterize the time-scales of acclimation processes and their relative impacts on ecosystem services.

Objective 2. Test the hypothesis that lags in ecosystem acclimation are already eroding ecosystem services.

Activities during this reporting period focused entirely on Objective 1, specifically leveraging Adler's NSF "Bromecast" project on climate change and cheatgrass invasion in western North America. Ecosystem acclimation is at the heart of this problem: to what extent will genetic diversity and adaptation amplify cheatgrass populations' ability to continue expanding under climate change?

What follows is a description of Bromecast activities in 2022:

First season of common garden experiments harvested

We began implementing a larger-scale common garden experiment in the spring of 2021 across four sites in the Intermountain West (two sites near Boise, ID; one in Dubois, ID; one in Cheyenne, WY). We established denuded plots using a 2 x 2 factorial design of cheatgrass density (low vs high) and plot temperature (white vs black gravel). Every site contains 40 plots (10 replicates of each density x temperature treatment in a randomized block design). We implemented the temperature treatments with black or white gravel to change surface albedo. To monitor treatment effects on abiotic variables, we installed four replicates of Decagon 5TM soil moisture and temperature sensors in low density black and white plots (a total of eight sensors) to quantify differences between temperature treatments. A denuded plot planted with cheatgrass at low density and two 5TMs installed serves as a control plot. An ambient plot with intact vegetation and four sensors (two thermocouple and two Decagon ECH2O sensors) installed at depth (20 and 50 cm) will help describe variation in temperature and moisture regimes across sites. We conducted additional gravel surface (infrared laser gun) and soil surface temperature (1 and 5 cm depth thermocouples) and moisture (5 cm soil moisture probe) microclimate measurements using handheld devices during bi-weekly common garden phenological surveys.

In the 2021-2022 season, each plot was planted with 100 cheatgrass seeds from 95 different genotypes for a total of 16,000 planted seeds across all sites. Before planting, we glued all cheatgrass seeds to toothpicks and labeled toothpicks of different genotypes with unique color combinations to more effectively track individual seeds in randomized planted grids and monitor source population demography and growth. In addition, we planted 10 toothpicks of 18 genotypes (180 seeds total) to destructively sample plants and measure morphological and physiological traits at the Boise high elevation white gravel plots and Boise low elevation black plots (to capture the greatest variability in traits).

We conducted a germination survey in Fall 2021/2022 and bi-weekly phenology surveys in Spring 2022, measuring seedling leaf length (during the germination and first three phenology surveys) and developmental stage (during all censuses) across all sites.

At the end of the 2021-2022 season, we harvested 10,000-12,000 surviving plants from all sites that we separated into individual coin envelopes and labeled with their respective site, grid position, final phenological stage and vegetative leaf length measurement. Plant samples are in the process of being analyzed for biomass weight and seed count.

In fall 2022, 80-90 seeds from 93 different genotypes were planted in each plot across sites for a total of 13,600 cheatgrass seeds for the 2022-2023 growing season. In addition, we planted 20 toothpicks of 28 genotypes (560 seeds total) for destructive harvest and trait measurements.

Satellite site experiments to validate model predictions

We have recruited volunteers across western North America to conduct “satellite experiments.” These experiments involve planting 150 locally collected seeds into both intact vegetation and plots where vegetation was removed by herbicide. We then track the demographic fate of each seed from emergence to fecundity, and describe species composition in its local neighborhood. Volunteers and funded project staff planned to conduct over 40 of these experiments in 2021-2022. We have now received at least some data from 29 sites. These experiments will be repeated in growing season 2022-2023. We will use half of the sites for model training, and the over half to validate model predictions.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Researchers interested in ecological impacts of climate change and climate adaptation science.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report

Training and Professional Development:

USU full-time staff Nikki Pirtel (MS level) continues to coordinate the field-work and sample-processing portions of the project, and to expand her skill-set. She has trained 6 USU undergraduates in field and lab techniques.

Dissemination:

A manuscript describing our methods for manipulating albedo and surface temperature is now in the second round of review at Plant and Soil. The manuscript focuses on results from the pilot study we conducted in 2020-2021.

Plan of Work:

We will continue to follow the plan of work outlined in our proposal. By the end of 2023, all our field data will be in hand (or in processing in the lab). The USU postdoc will begin in April 2023 and the CSU postdoc will begin in summer 2023, focusing on the data analysis and modeling objectives. We will also begin planning our first Bromecast network meeting in 2023.

Developing water conservation and pollution mitigation strategies for nursery and landscape industry

Project Director

Shital Poudyal

Organization

Utah State University

Accession Number

7002507



Developing water conservation and pollution mitigation strategies for nursery and landscape industry

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Reducing freshwater use and minimizing agrochemical runoff by the nursery and landscape industry.
2. Developing stress tolerance mechanism in ornamental plants.
3. Identifying and using alternate water for irrigation of ornamental crops.
4. Identifying emerging ornamental cultivars for xeriscaping and regional climate.
5. Disseminating research findings to growers, nurseries and other stakeholders.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

To accomplish the goal of both minimizing fertilizer use and fertilizer runoff, we conducted two different research. In the first research, we studied the effect of reduced phosphorus applications in fast and slow-growing ornamental ground cover, namely *Lysimachia nummularia* (Creeping Jenny) and *Catharanthus roseus* (Periwinkle). We found that applying phosphorus at the rate of 6 mg/L only once during the two-month growth cycle produced the same results as applying phosphorus at the rate of 6 mg/L at each irrigation. Lowering phosphorus can bring significant phosphorus saving and lower phosphorus runoff in leachate. Our next plan is to disseminate our findings to our target audiences. In the second research, we evaluated the potential of biochar, coconut coir and sphagnum moss to hold nitrate and phosphorus in the container substrate. The aim was to lower the amount of fertilizer leaching out of the container. We grew *Lavandula angustifolia* (Lavender) and *Solidago canadensis* (Golden baby) in a 3-gallon container and fertilized them with 50g of slow-release fertilizer per container. We collected leachate and are currently analyzing the concentration of phosphorus and nitrate in the leachate.

To meet the goal of Identifying emerging ornamental cultivars for xeriscaping and regional climate, we have already started field research (prepared field, planted plants and established them) where we will be evaluating the performance of newly developed ornamental cultivars namely Hibiscus (H2013-017-05), Philadelphus hybrid, Rosa (Petite Knockout®), Hibiscus (Purple Pillar®), Vitex (Blue Diddley®), Philadelphus (Blizzard), Ceanothus (Victoria), Ericameria (Aguirre™), Hibiscus (Pink Chiffon®), Pine (Pinyon Pine), Rosa (Cherry Frost™), Oso Easy® Double Pink, Oso Easy® Urban Legend® and Rosa Sitting Pretty™ and Rosmarinus at three different irrigation rate (80%, 50% and 20% of evapotranspiration). In addition, we will also be establishing field trial to compare the performance of ten different ornamental vines in Utah, Washington, California and Arizona. This multistate project is being funded by United States Department of Agriculture.

To reduce the use of freshwater, we conduct two different research projects. In the first project, we evaluated the potential of humic acid, wetting agents, super absorbent polymers and growth retardant to reduce irrigation water amount in fully grown Spirea japonica (Double Play® Pink) growing in the container. During mild water stress, humic acid treatment, wetting agent treatment and growth retardant increased soil moisture. Only growth retardant treatment maintained their soil water content during severe water stress. Even after one week of complete drought, plants receiving growth retardant treatments were still unwilted and green and their soil water content was well above 15%. We conducted similar research in the field where we amended soil with super absorbent polymers, vermiculite, coconut coir and peat moss. The initial data did not show any significant differences, which may be because our plants received treatment only for one month and the plants were just established. We will continue to collect data in the year 2023.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Our primary target audience includes large-scale nursery and greenhouse growers in Utah. Other target audiences also include people working in the green industry, such as landscape contractors, parks and recreational employees, garden centers, county extension agents, water district employees and botanical centers. Homeowner associations and individual homeowners are also among the beneficiary of our program.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

We had planned to start research on developing stress tolerance mechanisms in ornamental plants in the year 2022 and research for identifying new cultivars for xeriscaping and regional climate in 2023 however we switched timeline for those research.

Training and Professional Development:

We currently have two M.S. students working on these project. We conducted two research presentations in Center for Water-Efficient Landscaping field day. We also conducted one presentation in the Utah Water Conservation Forum Conference. We also had four research-related TV and radio presentations/interviews and one professional research presentation at 2022 NAPA biennial conference in Atlanta, Georgia.

Dissemination:

To disseminate research findings to growers, nurseries, and other stakeholders, we published eight related fact sheets and one related journal article. We have presented our findings at one national conference (Association of Nepalese Agricultural Professionals of Americas) and published about our research in the Center of water-efficient landscaping 2021 annual report. In addition, we trained green industry people about Landscape water budget and water use in four different Qualified water efficient Landscaping workshops at 3 different locations. We also incorporated a discussion session on irrigation scheduling, efficient irrigation, landscaping, turf irrigation, etc., at the Utah Chapter of The Wildlife Society 2022 annual conference.

Products:

Publications:

Other:

Poudyal, S. (2022). Container gardening tips for flowers. USU Instagram Extension Page.

Poudyal, S. (2022). Northern Utah Landscape Tips. USU Facebook Extension.

Poudyal, S. (2022). Landscape Tree Irrigation Calculator.

Poudyal, S. (2022). How Much Water Do Landscape Trees Require in Utah? An Irrigation Calculator.

Poudyal, S. (2022). Water-wise Landscape Ideas for Existing Landscapes. Utah State University Extension.

Presentations:

Burlakoti, S. (Presenter Only), Poudyal, S. (Author Only), CWEL Field Day 2022, "Optimizing P (phosphorus) application is crucial for a sustainable nursery production system," Utah State University, Online. (September 12, 2022)

Poudyal, S. (Presenter Only), CWEL Field Day 2022, "Ornamental plants research at Center for Water Efficient Landscaping (CWEL) to lower outdoor water and fertilizer use," Utah State University, Online. (September 12, 2022)

Poudyal, S. (Presenter Only), 2022 NAPA biennial conference, "Can irrigation return flow from nurseries be reused to irrigate ornamental plants?," Atlanta, Georgia. (May 27, 2022 - May 29, 2022)

Poudyal, S. (Presenter Only), Utah Water Conservation Forum Conference 2022, "Ornamental horticulture research and Extension work at CWEL," Conservation Garden, West Jordan, UT. (May 24, 2022)

Plan of Work:

We will complete both replications for substrate amendment research in the next reporting period. We will also complete data analysis for all the research mentioned above and start writing journal articles and fact sheets. We will also continue our ornamental cultivar trial research and climate-ready landscape vines research. In addition, we are planning to conduct two additional greenhouse research. The first would be an evaluation of wetland plants to remove nitrate from water and the other research would focus on irrigation water requirements at various light intensities for container-grown ornamental plants.

Project Director

Jessica Schadt

Organization

Utah State University

Accession Number

7001118



NC1190: Catalysts for Water Resources Protection and Restoration: Applied Social Science Research

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objectives:

1. Empirically test the role of catalysts, structures, and agency as drivers of change in conservation behavior, resource management and governance in a water context to determine the mechanisms and conditions by which catalysts are translated into individual, collective, and institutional action.
2. Understand and develop conceptual frameworks, typologies, and analytical models of individual, institutional, and collective actions and link these to social and ecological outcomes.
3. Identify, develop and evaluate adaptive strategies to achieve desired actions and capacities to protect water resources.
4. Assess the justice, equity, and inclusion dimension of water resources management and protection.

(2021): June -- Presentations on Objective 1 - empirically testing typologies using Mississippi River Basin, Chesapeake Bay, and other nutrient reduction strategies -- by multiple NC-1190 Members at University Consortium on Water Research Annual Conference

(2021): June -- Annual NC-1190 meeting following UCOWR Meeting (tentatively in Minnesota) to discuss progress on all objectives

(2021): Production on Special Issues in Decision Support Tools in Journal of Hydrology

(2022): Members organize and contribute to document on approaches to engagement and public participation in water conservation

(2024): Members organize and contribute to book -- "Opening Windows -- Emerging Issues in Natural Resources Conservation and Management" <https://www4.iasnr.org/opening-windows/>

(2023): Annual Meeting focusing on issues of social justice, diversity, equity, and inclusion in water quality conservation and management

(2025): Finalize and publish joint database of individual and collective actions (typologies) related to water management

(2025): Meeting to synthesize progress to date and new directions of research and collaboration

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Major activities completed (publications included in dissemination):

External Grants:

"Utah Soil Health Partnership: Utah Soil Health Network." (Co-PI) *United States Department of Agriculture -- Natural Resources Conservation Service, Conservation Innovation Grants On-Farm Trials* (\$1,710,288 million/\$274,125 portion), 2022-2026

“Using Smart Foodscapes for the Enhancement of Sustainability in Western Rangelands.” (Co-PI) *United States Department of Agriculture – National Institute of Food and Agriculture, Sustainable Agricultural Systems* (\$6.8 million/\$471,164 portion), 2021-2026

“Creating Corn Premiums through Precision Conservation and Sustainability Documentation, Continued.” (Co-PI) *South Dakota Corn Utilization Council* (\$200,000/\$20,218 portion), 2021-2022

“Thriving Agricultural Systems in Urbanized Landscapes.” (External evaluator and research) *United States Department of Agriculture – National Institute of Food and Agriculture, Sustainable Agricultural Systems* (\$9.986 million/\$379,730 portion), 2019-2024

Specific objectives met:

My research has contributed to each of the following project objectives:

1. Empirically test the role of catalysts, structures, and agency as drivers of change in conservation behavior, resource management and governance in a water context to determine the mechanisms and conditions by which catalysts are translated into individual, collective, and institutional action.
2. Understand and develop conceptual frameworks, typologies, and analytical models of individual, institutional, and collective actions and link these to social and ecological outcomes.
3. Identify, develop and evaluate adaptive strategies to achieve desired actions and capacities to protect water resources.
4. Assess the justice, equity, and inclusion dimension of water resources management and protection.

Significant results achieved, including major findings, developments, or conclusions (both positive and negative):

Notably, my work has continued to seek to improve the validity and reliability of measurements of conservation determinants and behavior using survey methods. Based upon experiments I have embedded within research projects, I have also been able to provide current recommendations for best practices for conducting survey research with rural and agricultural populations. A group that formed from this project recently published a piece in *Society and Natural Resources* focused on obtaining survey samples for research with agricultural populations. My work has also contributed to more nuanced theory predicting farmer conservation attitudes by highlighting the role of non-economic factors in producer behavior. I continue to work with a group of scholars from a variety of institutions (including many in the NC1190 group) to create and test better measures of sense of place in working landscapes. We have worked with a graduate student on a thesis on this topic which has only minor revisions as a peer-reviewed journal article. Finally, I have been training students in survey methods, natural resource sociology, and have had many of them working on projects relevant to this group.

Key impacts or other accomplishments realized: I have received additional funding to continue work in this line in Utah including awarded as a CO-PI on a USDA SAS grant to examine producers' willingness to use smart foodscapes in western rangelands and as a CO-PI on a NRCS CIG project which will focus on soil health in Utah and will run from 2021-2026.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Policymakers, conservation practitioners, agricultural producers, students, other academics

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

I have provided training and professional development for others in these presentations:

2022 “Interdisciplinary Collaboration and Knowledge Production.” Invited Panelist, *International Association for Society and Natural Resources*; Virtual Meeting.

2022 “Diverse Rural People and Places: Social Science Approaches for Research and Outreach.” Research and Innovation Course (Dr. Sarah Franklin), *University of Utah School of Medicine*.

2022 “Sociological Approaches to Rural Research.” Rural Research Panel, *Rural & Underserved Utah Training Experience (RUUTE) Program*, *University of Utah School of Medicine*.

2022 “Ranchers’ Use of Livestock Pest Products.” *South Dakota Ranchers’ Workshop*; White River, SD.

Over the course of the last year, I have also been able to attend (both online and in-person) a variety of conferences and seminars and conduct individual studies that have contributed to my professional development. These have provided me with the opportunity to share and get feedback on my research, plan for future projects/papers, network with other faculty and students, learn about new theoretical or methodological skills, and more. These include, but are not limited to, the annual meeting of the Rural Sociological Society, the International Association of Society and Natural Resources annual meeting, the NC1190 annual meeting, and a variety of seminars put on by related groups or institutions.

Dissemination:

Publications (Peer-Reviewed)

Clark, Jason D., **Jessica D. Ulrich-Schad**, Péter Kovács, Anthony Bly, and Edem Avemegah. 2022. “Farmer Adoption of Nitrogen Fertilizer Best Management Practices in South Dakota.” *Journal of Soil and Water Conservation*. doi:10.2489/jswc.2022.02152

Church, Sarah P., Chloe Wardropper, Emily M. Usher, Liam F. Bean, Ashlie Gilbert, Francis Eanes, **Jessica D. Ulrich-Schad**, Nicholas Babin, Pranay Ranjan, Jackie M. Getson, Laura Esman, and Linda S. Prokopy. 2022. “How does co-produced research influence adaptive capacity? Lessons from a cross-case comparison.” *Socio-Ecological Practice Research*. DOI:10.1007/s42532-022-00121-x

Ulrich-Schad, Jessica D., Shuang Li, J. G. Arbuckle, Edem Avemegah, Kathryn J. Brasier, Morey Burnham, Anil Kumar Chaudhary, Weston M. Eaton, Wei Gu, Tonya Haigh, Douglas Jackson-Smith, Alexander L. Metcalf, Amit Pradhananga, Linda S. Prokopy, Matthew Sanderson, Emma Wade, & Adam Wilke. 2022. “An Inventory and Assessment of Sample Sources for Survey Research with Agricultural Producers in the U.S.” *Society and Natural Resources* 35(7): 804-812.

Fairchild, Ennea, **Jessica D. Ulrich-Schad**, Peggy Petzelka, and Zhao Ma. 2022. “The Lay of the Land: What We Know About Non-Operating Agricultural and Absentee Forest Landowners in the U.S. and Europe.” *Journal of Environmental Management* 313(1):114991.

Academic Conference Presentations

2022 Edem Avemegah, **Jessica D. Ulrich-Schad**, Candace May, Péter Kovács, & Jason Clark. “Understanding Farmers’ Adoption of Conservation Tillage in South Dakota Using a Modified Theory of Planned Behavior.” *Rural Sociological Society Annual Meeting*; Westminster, CO.

2022 Elizabeth Bennett, Morey Burnham, **Jessica D. Ulrich-Schad**, J. Arbuckle, & Weston Eaton. “Testing Modified Sense of Place Measures on Adoption of Cover Crops in Working Landscapes in Iowa.” *Rural Sociological Society Annual Meeting*; Westminster, CO.

2022 **Jessica D. Ulrich-Schad**, Edem Avemegah, Sarah P. Church, Brennan Radulski. “Agricultural and Non-Agricultural Residents’ Perceptions of Water Quality and Interventions: Finding from the Chesapeake Bay Watershed.” (Poster). *International Association for Society and Natural Resources Annual Meeting*; San Jose, Costa Rica.

Plan of Work:

Over the following year I plan to publish a number of peer-reviewed papers and extension articles from survey and interview data collected previously in South Dakota and the Chesapeake Bay Watershed. I will work with graduate students and colleagues to accomplish this. We will also disseminate the results via workshops for the public/stakeholders (Thriving Agriculture Project, in particular) and academic conferences. I also have a number of Utah-based projects that will turn to data collection mode including one focused on soil health where we will survey both crop advisors and producers about the role of soil health in their management practices.

Nutrient Cycling in a Livestock-Forage System

Project Director

Rhonda Miller

Organization

Utah State University

Accession Number

1026546



Nutrient Cycling in a Livestock-Forage System

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Overall Goal

The goal of this project is to examine and more fully understand nutrient cycling in agricultural livestock-forage systems, with a specific focus on the impact of manure management and other production technologies, in a cold, arid climate such as is found in Utah and the Intermountain West. This information will then be used to help develop best management practices.

Specific Objectives

1. Evaluate the effect of forage species and their rooting structure on nutrient cycling.
2. Evaluate the impact of production technology on forage nutrient content.
3. Examine the effect of soil, temperature, moisture, and manure type on mineralization rates and nutrient losses.
4. Examine the effect of tannins on gaseous emissions.
5. Examine the effect of manure management practices on nutrient cycling.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: Evaluate the effect of forage species and their rooting structure on nutrient cycling.

Leachate sample collection continues. Fertilization levels were modified. Beginning soil samples for the new fertilization levels were taken. Leachate sample analysis is underway.

Objective 2: Evaluate the impact of production technology on forage nutrient content.

A field study was conducted at Cache Junction, UT examining the impact of different crimper systems on alfalfa hay quality. Dry down, windrow height, and crimp counts were measured. Forage samples were collected and are being analyzed for crude protein content. Data analysis for swather study is underway.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Other researchers examining nutrient cycling and environmental impacts in agricultural systems, ag professionals including NRCS, Extension agents, and producers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report.

Training and Professional Development:

Attended the Waste-to-Worth Conference in Maumee Bay, Ohio.

Dissemination:

Presented preliminary nutrient cycling results from grass monoculture and grass-legume mixture study at Waste-to-Worth conference, and at Utah Grazing Institute.

Plan of Work:

Objective 1: Continue with sample collection and analysis

Objective 2: Complete analysis and present results

Climate and Parent Material Controls on Soil Development in Western Ecosystems: Understanding the Past and Adapting to the future

Project Director

J Boettinger

Organization

Utah State University

Accession Number

1022936



Climate and Parent Material Controls on Soil Development in Western Ecosystems: Understanding the Past and Adapting to the future

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The ultimate goal is to characterize pedogenic thresholds in soils over environmental gradients and assess the impacts of these thresholds on ecosystem services. The exact scope of the work will depend in part on the external funding obtained in conjunction with this project. Requested UAES budget will provide the baseline funding for the proposed scope of work. We intend to pursue additional funds when calls for proposals are issued by USDA and other funding agencies.

Objective 1: Investigate the influence of climate and volcanic ash on soil development on basalt lava flows on the western slope of Haleakala, Maui, Hawaii. Land use on Maui shifts from monocultures of sugarcane to livestock grazing and ecotourism, and there is growing interest in sequestering soil carbon and developing markets for niche specialty crops. The results of our work can advance our understanding of soil development while providing useful soil information for land managers. The research should be significant in that it builds on previous research on soil development and pedogenic thresholds on the islands of Hawaii and Kauai. In addition, there is a soil survey update on Maui in progress, and there is opportunity to collaborate and share data with USDA NRCS, while enhancing the progress and added value of the resulting soil survey.

Objective 2: Expand the soils component of a vegetation geo-climatic zonation in the Rocky Mountains of northern Utah. The original work was a coarse-scale vegetation geo-climatic zonation based on vegetation, climate, and soils that provided a framework for a comprehensive ecosystem survey, which was missing in the central Rocky Mountains. The vegetation-

geoclimatic zonation explicitly accounted for the influence of the physical environment on the distribution of vegetation within a complex landscape typical of the central Rocky Mountains. Given the diversity of parent materials across this region, there is opportunity to mine existing data to evaluate the influence of climate/elevation, parent material, and vegetation on soil development and pedogenic thresholds.

Objective 3: Investigate coevolution of rare endemic plants, soils, and landscapes in the Colorado Plateau and Great Basin physiographic provinces of Utah. This research will build upon previous work on the soil habitats of rare endemic plants in the Uinta Basin and work in the Bear River Range.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Maui is one of five Hawaiian Islands affected by orographic climate effect, exhibiting a massive precipitation gradient across western Haleakalā. However, high variability of volcanic ash deposits as a parent material across the study area complicates the ability to isolate the influence of climate on soil formation. Additionally, little is documented about the spatial extent of ash deposition, frequency and intensity of volcanic ejecta events, and composition of ash. Therefore, andic soils, which contain short range order (SRO) aluminosilicates and iron oxides that result in unique soil chemical and physical properties, are challenging to map. Using environmental and andic soil property data from 16 pedons sampled in the study area—bulk density, phosphate retention, and aluminum plus ½ iron extracted by ammonium oxalate—we applied multiple linear regression to create spatial prediction models of these three soil properties. The mean prediction for Natural Resources Conservation Service (NRCS) pedons showed a soil classification accuracy of 50% in the study area for Andisols (data to 60 cm), andic intergrades (data to 75 cm), and non-andic soils. Soil property predictions using depth-weighted average data to 1 m increased soil classification accuracy of Andisols to 87.5%, andic-intergrades to 100%, and non-andic soils to 83.3%. Whether a soil exhibits andic soil properties within 60 or 75 cm is irrelevant when considering prior or current presence of ash in a soil. Accounting for all available pedon data with depth proves most important when attempting to predict andic soils.

Undisturbed soil cores may be best for studying field processes in the lab, but core variability can make them difficult to use. The goal of this study was to develop a method to make packed columns that have one-step outflow curves similar to those of undisturbed cores. Undisturbed 15.2-cm-long cores and bulk soil were obtained from a sandy loam permanent pasture (Pasture) and a sandy clay loam uncultivated field (Springhill). Two packing methods were tested: ordinary-packed columns were made by compressing bulk soil to the average core bulk density, and layered columns were made by duplicating the average bulk densities of three core layers. Outflow was recorded from pressure head of -7.6 cm to -133 cm from newly packed columns and after drying to produce shrinkage cracks. A new outflow model that included initial water content (q_i), final water content (q_f), and time to reach 63.2 % outflow (T) was fit to the data by adjusting a time exponent b (average $r^2 = 0.995$). Column parameters were compared to cores by equivalence testing. Drying reduced q_i and q_f , possibly due to shrinkage cracks that increased drainable porosity. Columns of the Pasture soil had significantly greater T than natural cores, possibly due to lack of root-formed pores in the columns. Overall, layered and dried columns were most similar to natural cores and less variable. These methods and results may help make packed soil columns more representative of undisturbed soil.

In drylands, there is a need for controlled experiments over multiple planting years to examine how woody seedlings respond to soil texture and the potentially interactive effects of soil depth and precipitation. Understanding how multiple environmental factors interactively influence plant establishment is critical to restoration ecology and in this case to broadscale restoration efforts in western U.S. drylands dominated by big sagebrush (*Artemisia tridentata*). We planted sagebrush seedlings across a range of soil textures and depths in the southern portion of the species' range, on the Colorado Plateau, USA. We evaluated survival of repeated plantings of caged and uncaged seedlings over 2 years across 20 plots in wet versus average precipitation years at one site, and examined broader patterns of sagebrush seedling survival during an average precipitation year in 56 plots across four sites. First-year survival was >9× higher under wet than average precipitation. Under favorable (wet) conditions, early sagebrush seedling survival was highest on coarser soils, especially those that also had a shallower restrictive layer (e.g. 50–100 cm). Under average precipitation, soil texture and depth effects on survival of newly planted seedlings were much weaker, but older (>1 year) seedlings benefitted from growing on coarser-textured soils. It may be possible to increase survival by sheltering seedlings with small mesh cages, which likely improve moisture availability. Our results provide new insights into environmental factors that limit woody seedling survival in drylands and illustrate that planting in wet years and incorporating detailed soil setting information could increase survival of sagebrush seedlings in restoration projects.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Partners in the National, Western, and Utah Cooperative Soil Survey, particularly USDA Natural Resources Conservation Service, USDI Bureau of Land Management; scientists, students, and land managers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report

Training and Professional Development:

This project provided opportunities for research training for one doctoral-level graduate student. The project also provided training opportunities in field observation and interpretation of soils for 18 students in PSC 5130/6130, a senior/graduate-level course in Soil Genesis, Morphology, and Classification at Utah State University.

Dissemination:

Results of the Maui, Hawaii, research were disseminated by submitting a manuscript to Soil Science Society of America Journal on November 5, 2022.

Results of the undisturbed core vs. packed soil column research were disseminated by submitting a manuscript to Soil Science Society of America Journal on July 20, 2022. The manuscript was returned for revisions, and has been resubmitted to the journal.

Results of the woody seedling response to soil texture and the potentially interactive effects of soil depth and precipitation were disseminated by submitting, revising, and publishing a manuscript in the journal, Restoration Ecology.

A paper on a sequence of soils formed in Pleistocene pluvial Lake Bonneville deposits in Cache Valley was presented orally at the 2022 World Congress of Soil Science, August 2, 2022.

Publications:

Other:

Hodges, R. C., & Boettinger, J. L. (2022). Predicting the Extent of Andic Soils of Western Haleakala, Maui. Salt Lake City, UT: ASA, CSSA, SSSA International Annual Meeting.

Presentations

Hodges, R. (Author Only), Boettinger, J. L. (Author Only), 2020 ASA-CSSA-SSSA International Annual Meeting, "Soil Genesis across a Climo-Lithosequence of Western Haleakala?," American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Virtual. (November 11, 2020 - Present)

Plan of Work:

Prepare and submit for possible publication additional manuscripts on soil development and distribution in Maui, Hawaii. Prepare and submit for possible publication a manuscript on the soil properties required by the rare endemic plant, shrubby reed-mustard.

Identification and development of grasses for sustainable turfs in the Intermountain West

Project Director

Paul Johnson

Organization

Utah State University

Accession Number

1023008



Identification and development of grasses for sustainable turfs in the Intermountain West

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Our overall goal is to evaluate and develop turfgrasses that are more tolerant of stresses--environmental and human caused, and be sustainable systems that require low levels of inputs. Meeting these goals will allow these turfgrass areas to continue providing ecosystem services and benefits to the urban living environments.

More specifically, our goals and objectives are:

- 1) Select and evaluate bluegrasses and other common turfgrasses and select alternative species for acceptable turfgrass quality and use in sustainable turf systems appropriate for Utah and the Intermountain West region.
- 2) Further improvements in salinity and drought stress tolerance of Poa.
- 3) Evaluate and improve seed production traits in bluegrasses including vernalization characteristics, using Poa annua as a model species.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Our cooperation with the National Turfgrass Evaluation Program (NTEP) continued as we have continuously for 24 years to evaluate turfgrasses best adapted conditions in northern Utah and the Intermountain West. We have focused most of these trials towards drought tolerance traits and susceptibility to insect pests, particularly the billbug species. Both of these stresses are the main challenges for the frequently used turfgrass species in providing good performance where turf is desired and adapted in the landscape. We submitted our data to NTEP and will be further reported through our Center for Water Efficient Landscaping (CWEL) publications. The best place for presentation of this data is on the NTEP website (<https://ntep.org/>). The trials we conducted were: 2018 Kentucky bluegrass drought; 2020 Bentgrass putting green standard; and 2020 Fine fescue standard. New trials planted this year is the 2022 Cool-season water use trial and the 2022 Perennial ryegrass trial.

In 2022, we also began cooperation with the United States Golf Association and the turfgrass breeding program at Texas A&M in initial evaluation of cold tolerant zoysiagrasses. Some highlights of 2022 include:

Kentucky bluegrassThe Kentucky bluegrass (Poa pratensis) variety trial was again affected by billbug (Sphenophorus spp.) insects with some loss of cover. This loss in turf coverage occurred because of the combination with low irrigation replacement. Parts of the plot with higher irrigation replacement tolerated the damage better and fully recovered in fall.

BentgrassVery large differences exist in canopy density and uniformity as expected. Varieties that initially performed well for turfgrass quality were PST-0HR and Oakley with Piper, Spectrum, and PVF-PV-2 close behind. Fine fescueAll entries exhibited good to very good turfgrass quality. Its difficult to make significant conclusions in the year after establishment. Chewings fescue and strong creeping red fescue varieties tended to perform slightly better than the others but none were below acceptable quality in 2022.

Cool-season water useAll plots were fully established and provided good turfgrass quality going into winter. Mowing to fairway height started prior to winter.

Perennial ryegrassAll plots were fully established and provided good turfgrass quality going into winter.

ZoysiagrassIt was intended to put this trial in the ground in fall 2021 but due to various reasons, it was best to wait and plant the vegetative material in spring 2022. All established well and exhibited a range of spreading, growth, and turfgrass quality characteristics. This was expected. The most informative will be survival in winter 2022-2023.

In cooperation with Dr. Shaun Bushman at the USDA-ARS Forage & Range Research Lab, we concluded initial efforts in sequencing Poa annua. My role was minor in this initial phase.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Turfgrass scientists, turfgrass professionals, extension personnel, industries related to turfgrass management and seed production

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

Attended the Crop Science Society of America annual meeting in Baltimore Maryland and the International Turfgrass Society meeting in Copenhagen in 2022. I also participated the online Heart of Higher Education workshop in June followed by the "Taking it Home" five month program from July to November which related to leadership topics.

Dissemination:

One refereed article was published and another accepted in 2022. One article is in cooperation with a visiting scientist with my role as editing language and clarifying for a US audience. The accepted publication is related to our group's work with the sequencing and association of parental species *Poa infirma* and *Poa supina* leading to *Poa annua*. Data relating to the National Turfgrass Evaluation Program trials are published on their website at <http://ntep.org/>. The NTEP work was also reported in our Center for Water Efficient Landscaping annual report and website (<https://extension.usu.edu/cwel/>).

Products:

Publications:

Refereed Journal Articles

Chai, X., Sun, X., Cui, X., Johnson, P. G., & Fu, Z. (2022, December 13). Clonal integration systemically regulates leaf microstructure of *Bouteloua dactyloides* interconnected ramets to better adapt to different levels of simulated insect herbivory. *AoB Plants*.

Robbins, M. D., Warnke, S. E., Maughan, J., Huff, D. R., Benson, C. W., Jellen, E. N., Johnson, P. G., & Bushman, S. (in press). Chromosome-scale Genome Assembly and Annotation of Allotetraploid Annual Bluegrass (*Poa annua* L.). *To appear in Genome Biology and Evolution*.

Plan of Work:

We will continue the various NTEP trials and the zoysiagrass trial currently underway and will be pursuing a new Kentucky bluegrass trial, possibly two from NTEP. We will also start new research related to genes activated during flowering and those affected from the plant growth regulator ethephon.

Resource - Positive Urban Landscapes

Project Director

K Kopp

Organization



Resource - Positive Urban Landscapes

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The proposed research will consist of efforts in three main areas: 1) Evaluate water use, plant health and quality of integrated turfgrass and ornamental landscapes, differing only in plant material, under initial establishment conditions and subsequent dry-down conditions, 2) Evaluate and maximize C sequestration of integrated turfgrass and ornamental landscapes under varying management practices (mowing, fertilization, irrigation), 3) Develop LCAs of integrated turfgrass and ornamental landscapes in order to characterize resource-positive landscapes for the state and region.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The project consists of research efforts in three main areas: 1) Evaluation of water use, plant health and quality of integrated turfgrass and ornamental landscapes, differing only in plant material, under initial establishment conditions and subsequent dry-down conditions, 2) Evaluation and maximization of C sequestration by integrated turfgrass and ornamental landscapes under varying management practices (mowing, fertilization, irrigation), 3) Development of life cycle analyses of integrated turfgrass and ornamental landscapes in order to characterize resource-positive landscapes for the state and region.

With regard to Objective 1, following enhanced instrumentation of the plots in 2021, the landscapes continued to be established and maintained in 2022. Standard maintenance practices for pruning, weeding, mulching, fertilizing, and irrigation were continued. Some plots experienced significant turfgrass insect damage in 2021 and were replanted in 2022 which delayed the onset of experimental treatments.

With regard to Objectives 2 and 3, a graduate student for the project was identified and admitted to USU and has completed their first semester. The student began course work but also began a scientific literature review of research and findings relevant to the project. Planning continued for initiation of the work in 2023 and additional funding sources for the project were explored.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences include federal and state water agencies, water purveyors, municipalities and members of the landscaping and irrigation industries. Ultimately, individual citizens will also benefit from the findings.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Having had insect damage to the lysimeter plots at the UAES farm in Kaysville, UT last year, it is likely we will have them again this year. Planning is underway for preventative treatment. The location of these plots, roughly 1 hour + from main campus in Logan, also continues to prove challenging in terms of routine plot maintenance.

Training and Professional Development:

None to report.

Dissemination:

The plans for this project have been disseminated broadly in water conservation-related meetings and conferences in the state, region, and nation. The Alliance for Water Efficiency (primary source of project funding) has also been kept apprised of project status.

Products:

Publications:

Refereed Journal Articles:

Evans, S., Kopp, K., Johnson, P. G., Hopkins, B., Dai, X., & Schaible, C. (2022, September 07). Comparing Smart Irrigation Controllers for Turfgrass Landscapes. *HortTechnology*, 32(5), 415-424.

Plan of Work:

Objective 1) Evaluation of water use, plant health and quality of integrated turfgrass and ornamental landscapes, differing only in plant material, under initial establishment conditions and subsequent dry-down conditions

Collaboration with Dr. Youping Sun will continue on this objective. We have replanted/resodded the turfgrass areas that were damaged in 2021 and thinned/removed other plants as needed to better reflect actual landscapes. We anticipate collecting soil moisture data and leachate from the plots beginning in the spring of 2023.

Objective 2) Evaluation and maximization of C sequestration by integrated turfgrass and ornamental landscapes under varying management practices (mowing, fertilization, irrigation).

Research plots at the UAES Greenville Research Farm have been prepared (plant removal, irrigation system maintenance) for landscape installation in spring/summer 2023. Prior to installation, four experimental treatments will be characterized for this purpose.

Objective 3) Development of life cycle analyses of integrated turfgrass and ornamental landscapes in order to characterize resource-positive landscapes for the state and region.

Drs. David Rosenberg (Civil and Environmental Engineering) and Steven Wilcox (Applied Economics) have been identified as collaborators on the project and committee members for the graduate student on the project. Planning meetings and site visits will be scheduled to facilitate their involvement.

Management and Policy Challenges in a Water-Scarce World

Project Director

G Cardon

Organization

Utah State University

Accession Number

1021485



W4190: Management and Policy Challenges in a Water-Scarce World

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

3. Evaluate and compare coordinated/integrated management of water sources and land use practices.

Comments: Intensive agriculture and input use are on the rise, placing pressure on water availability and quality in many locations. Research undertaken in this objective examines the effects of land use change on water quantity and quality. It also explores the feasibility of alternative water sources. Results will provide critical insights and data that will help guide future planning and decision-making as well as the development of management interventions.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Accomplishments this reporting period included the validation and calibration of baseline soil and plant canopy maps that have now been used to delineate variable-rate irrigation and fertility management zones for deployment in experimental tart cherry orchards in Utah County. This was foundational to the establishment of a multi-year research project looking at the potential for variable-rate water and fertility management in these high value fruit crops. The validation and calibration work required extensive statistically designed soil sampling to capture the soil variability observed in bulk soil conductivity in our study orchards. These samples were processed for soil texture, organic matter content, salinity and other physical and chemical properties affecting bulk soil electrical conductivity used to remotely map the bulk variation in soil conditions. The primary soil properties that correlated most strongly with bulk electrical conductivity, were consistently the sand and silt contents of the soil. From these maps, four treatment zones for fertility and irrigation management have been determined, plots delineated, and treatments prepared for deployment in the spring of 2023.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Irrigators and irrigation system water managers, and resource management policy makers at the local, state and regional levels.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None foreseen excepting the potential inclusion of additional test sites in western Utah County and in Caldwell, Idaho.

Training and Professional Development:

One PhD student was trained on the mapping and validation efforts of this project. Another PhD student and another MS student are being trained as well on the grant, but are assigned additional aspects of the project (yield mapping, correlation and refinement of satellite imagery with local drone imagery, and disease and insect pest incidence with soil and plant canopy conditions).

Dissemination:

The research information produced by the noted studies has been disseminated in several national and regional professional conferences and local departmental seminar presentations.

Publications/Presentations:**Refereed Journal Articles:**

Sun, H., Kopp, K., Cardon, G., & Jones, S. B. (2021, January 28). Numerical simulation of water and nitrogen transport in three turfgrass systems. *International Turfgrass Research Society Journal*, 2021, 1-20.

Wytsalucy, R., Drost, D. T., Dai, X., Black, B. L., & Cardon, G. (2021, October). Improving Navajo spinach (*Cleome serrulata* Pursh) seed germination with cold stratification and hormone additions. *Native Plants Journal*, 22(3), 268-278.

Wytsalucy, R., Gasic, K., Robbins, M., Cardon, G., Drost, D. T., & Black, B. L. (2020, April). Genetic analysis of peaches grown by Native Americans in the North American Southwest. *Journal of the American Pomological Society*, 74(2), 76-83.

Other:

Yost, M., Cardon, G., Allen, L., Sorenson, B., Egbert, K., Creech, J. E., Ransom, C., & Ramirez, R. (2020). Chemigation guide. USU Extension.

Presentations:

Cardon, G. (Presenter & Author), Department Seminar, "Improving Tart Cherry Productivity and Profitability Through Variable-Rate Precision Management: A New Multi-State, Multi-Discipline Project," University of Minnesota, Soil, Water and Climate Dept., St. Paul MN. (February 9, 2022)

Plan of Work:

The second year of this study will result in the deployment of the variable-rate treatments for irrigation and fertility management. The effect of these differential treatments on tree growth, yield, fruit quality, and disease and pest incidence will be evaluated in tart cherry experimental orchards. Additional orchard sites will now be mapped and characterized for deployment of anticipated experimental units in Tintic Valley, Utah County and in Idaho's Treasure Valley region near Caldwell, Idaho, which are not yet part of the study, but have expressed interest in involvement based on professional presentations made by the PI's and graduate students on the project.

Soil, Water, and Environmental Physics to Sustain Agriculture and Natural Resources

Project Director

Scott Jones

Organization

Utah State University

Accession Number

1021245



W4188: Soil, Water, and Environmental Physics to Sustain Agriculture and Natural Resources

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Connect new understandings of storage and transport of mass and energy to assess environmental change.
2. Develop and test new instrumentation, methods and models to improve the mechanistic understanding of soil processes and the quality of soil information and knowledge.
3. Integrate scale-appropriate methods to improve decisions related to the management of soil and water resources.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Visiting Assistant Professor of Applied Mathematics, Asghar Ghorbani, from Ferdowsi University of Mashhad, Iran, arrived at USU in August to begin a yearlong sabbatical. Dr. Ghorbani along with Morteza Sadeghi (adjunct @ USU) and Scott Jones collaborated on a Physics-Constrained Machine Learning approach to develop new soil water flow equations. Dr. Ghorbani has already derived improved hydraulic functions that will be the basis of a peer-reviewed publication under development. We are also working on a number of grant funding proposals to support our joint research efforts.

Scott Jones and Bruce Bugbee continued collaboration on a NASA-funded research grant to improve plant growth media for pick and eat production in reduced gravity conditions. Our 2022 accomplishments included:

1. We evaluated more than eight types of growth media and peat-based growth media resulting in higher hydraulic conductivity and thus faster, more consistent growth rates than several synthetic media or calcined clay aggregates.
2. The growth rate and nutrient content of mizuna lettuce were not decreased through eight successive crops in the same peat-based media.
3. The use of a carefully defined nutrient solution through fertigation provided more consistent plant nutrition than the use of slow-release fertilizers.
4. We evaluated the idea of launching pre-wetted hydrophilic growth media at -10 kPa (-1 m) matric potential, which ensures no free water release from media at 6g.
5. Numerical simulations of hydrodynamics at 1g in layered growth media based on particle size, yielded reasonable approximations of uniform water distributions in mg.
6. Controlled, positive pressure water delivery resulted in more rapid growth rates and less root growth on porous tubes than sustained negative water pressure delivery.
8. Peat media retained viable structure after eight cropping cycles.
9. Most plant roots degrade within three days of harvest and do not negatively affect re-seed germination or seedling growth and development.
10. We found roots displacing up to 6% of the total 10 cm deep root zone volume, which is a significant reduction in pore space for low-porosity growth media, e.g. Turface.

Collaboration with the University of Arizona (M. Tuller) and the University of Florida (E. Babaeian) continued with development of a book chapter titled, "Proximal Sensing of Soil Moisture" in the Encyclopedia of Soils in the Environment, scheduled for release in August 2023.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Researchers including hydrologists, soil scientists, ecologists and engineers. Policy makers that address issues related to the environment. NASA scientists and administrators interested in plant growth in reduced gravity. Students conducting research within environmental and agricultural areas.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report.

Training and Professional Development:

I attended several professional meetings including the Soil Physics Working Group meeting in early January and the Soil Science Society of America Meeting in November.

Chihiro Naruke, a Ph.D. student in Utah State University's Department of Plants, Soils & Climate, was awarded first prize in her division at the American Geophysical Union conference for presenting her findings on how root growth affects the pore space

of soil. Naruke's research is aimed at predicting and designing the ideal plant growth system in microgravity conditions.

Naruke was also awarded first prize in the *Soil Physics & Hydrology Division* student oral and poster competition at the Soil Science Society of America's Annual Meeting held in Baltimore, Maryland November 7-10, 2022.

Dissemination:

One book chapter, two peer-reviewed manuscripts and two reports were submitted. Three oral presentations were delivered to in-person and online audiences.

Products:

Publications:

Book Chapters:

Tuller, M., Babaeian, E., & Jones, S. B. (2023). Proximal Sensing of Soil Moisture. *Encyclopedia of Soils in the Environment (2nd ed.)*.

Refereed Journal Articles:

Chen, J.-J., Sun, Y., Kopp, Oki, L., Jones, S. B., & Hipps, L. E. (in press). Physiological and canopy temperature responses to drought of four *Penstemon* species. *To appear in HortScience*.

Chen, J.-J., Sun, Y., Kopp, K., Oki, Jones, S. B., & Hipps, L. E. (2022, May 18). Effects of water availability on leaf trichome density and plant growth and development of *Shepherdia × utahensis*. *Frontiers in Plant Science*, 13, 1-14.

Norouzi, S., Sadeghi, M., Tuller, M., Liaghat, A., Jones, S. B., & Ebrahimian, H. (2022). A Novel Physical-empirical Model Linking Shortwave Infrared Reflectance and Soil Water Retention. *J. Hydrology*, 614, 128653.

Other:

Jones, S. B., Bugbee, B. G., & Bingham, G. (in press). Final Report: Design, Monitoring and Management Approaches for the Root zone in Microgravity.

Jones, S. B., Bugbee, B. G., & Bingham, G. (in press). Interim Report: Design, Monitoring and Management Approaches for the Root zone in Microgravity.

Presentations:

Jones, S. B., Naruke, C., Blakeslee, A., Fatzinger, B., Bugbee, B. G., ASA, CSSA, and SSSA International Annual Meetings, "Plant Growth Porous Medium Design and Management Considerations for Reduced Gravity.." (November 8, 2022)

Naruke, C., Fatzinger, B., Bugbee, B. G., Blakeslee, A., Jones, S. B., ASA, CSSA, and SSSA International Annual Meetings, "Numerical Simulation for Water and Plant Root Uptake Under Various Gravity Conditions in Containerized Soilless Media.." (November 7, 2022)

Jones, S. B., Sadeghi, M., Robinson, D. A., W4188 Soil Physics Working Group Virtual Meeting, "Utah State University Report," USDA. (January 3, 2022 - January 4, 2022)

Other Products:

Instruments or Equipment The automated water retention measurement apparatus was further evaluated for coarse porous media (potting soils). A publication is in preparation for submission for peer-review. The system provides greater accuracy and repeatability of water retention measurements in coarse-textured plant growth media beyond what was achievable using standard hanging column methods, including both draining and wetting processes.

Plan of Work:

NASA project Plan: i) One Ph.D. student will continue work on the porous media physics, transitioning to postdoc this year with several additional manuscripts from the dissertation in the works. Presentations of our research results from this project will be presented at the ASA-CSSA-SSSA annual meeting in St. Louis, MO during November 2023, ii) Design and fabrication of the Phase B plant growth rooting system electrical and mechanical aspects will be carried out in concert with Space Dynamics Laboratory. iii) Prototype root modules will be developed for plant growth studies in Ohalo III-like chambers, and iii)

Characterization and numerical modeling of the proposed compound plant root module system will be carried out.

Proposals addressing subsurface soil moisture and the means to estimate soil profile moisture content from limited water content information will be submitted. The realization of soil moisture within the root zone will be further developed as an estimator of biomass production for grazing animals or fire risk assessment.

We may also propose to address the recharge to groundwater using novel analytical algorithms we are working to develop.

We are also working toward collaboration and federal proposal development on the topic of preferential flow measurements and modeling in porous media.

Closing Out (end date 06/12/2024)

[Applied Research Synthesis to Inform Resource Decision-Making Related to Drought Resiliency](#)

Project Director

R Gillies

Organization

Utah State University

Accession Number

1019958



Applied Research Synthesis to Inform Resource Decision-Making Related to Drought Resiliency

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

- Task 1: Earth system modeling for decadal prediction
- Task 2: Snowpack reconstruction for mapping
- Task 3: Streamflow reconstruction and prediction
- Task 4: Evapotranspiration (ET) monitoring and prediction
- Task 5: Soil moisture modeling and prediction

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Research indicates: (a) Precipitation and Natural Water Availability have shown a slight declining pattern and less variability (after 1990) over all the four regions. (b) Precipitation and NWA have indicated a significant correlation (at 95% significance level) during current year and +1 year between them. Other parameters (soil moisture, air temperature, and potential evapotranspiration) have not shown any significant correlation. (c) Northern Utah has a precipitation decline at the rate of 0.30 mm/decade and a maximum air temperature increment at 0.34°C/decade.

(a) Great Salt Lake basin (the portion covering northern Utah) has lost ~2.34 mm water per year from its total water storage since 2002 and has hit its lowest storage in 2021. (b) The water storage deficit index (WSDI) trend is well aligned with self-calibrated Palmer Drought Severity Index with a significant correlation at a 95% significance level and show similar fluctuations. (c) WSDI captures the drought events (2002-05, 2011-17, 2020-present) efficiently along with other parameters.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Extension and Outreach

Water Managers - State officials involved in State Homeland Security

Decision-makers - State and Local involved with drought management

Specifically:

Utah Department of Natural Resources, Division of Water Resources
Salt Lake City Department of Public Utilities
The Utah Farm Bureau Federation, the state's largest voluntary organization of farmers and ranchers
Southern Rockies Landscape Conservation Cooperative Network
Jordan Valley Water Conservancy District
Provo River Water Users Association
Weber Basin Water Conservancy District
NOAA-Western Water Assessment
NOAA - NIDIS
Laughlin Water Associates (private industries)
Central Utah Water Conservancy District.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

The climate center research scientist (Hydroclimatologist), Avik Mukherjee, has been mentored by Dr. Robert Gillies and Dr. Simon Wang. Dr. Mukherjee has completed his OPT and has taken a position elsewhere. We are expecting a research publication soon based on the preliminary results of the project.

Dissemination:

WWW - through the climate.usu.edu portal

Peer reviewed publication

Plan of Work:

Region-wise application of water balance approach to calculate natural water availability and identifying the precipitation variability to deliver a more precise and effective approach for estimating a particular region's natural water availability using the water budget approach. The analyses will help to provide a unique way of understanding water shortage or surplus for drought assessment.

Closing Out (end date 06/12/2024)

[Agricultural Climate Change Adaption Strategies for Native American Reservations](#)

Project Director

Kynda Curtis

Organization

Utah State University

Accession Number

1019595



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

This project seeks improve the economic sustainability of agriculture on Native American reservations in the face of climate change effects such as:

- Less overall water availability, especially late in the season
- Periods of flooding, too much water
- Warmer temperatures, increased growing degree days
- Larger variability in temperatures
- Increased pest pressure
- Reduced productive rangeland
- Increased erosion on range and fallow areas

Sustainable agricultural systems will assist in maintaining tribal social and cultural traditions and enable tribal members to remain on their reservation and participate within their community. Maintaining a strong agricultural economic base on reservations will also build the economic viability of surrounding rural areas dependent on local production adjacent to reservations.

This project has six primary objectives:

1. Examine the primary cropping systems, water availability, and irrigation systems on native American reservations in Utah.
2. Evaluate the potential economic feasibility of alternative cropping systems including low water-use, heat resistant, high CO2 resistant marketable crops and high-value crops on reservations.
3. Evaluate the potential economic feasibility of ag-related enterprises (food product development, food tourism, etc.) on reservations.
4. Assess the economic, social, and cultural benefits and impediments to producer adoption of alternative cropping systems and ag-related enterprises.
5. Assess educational and technical assistance needs.
6. Disseminate study results and information to agricultural producers and policy makers on reservations.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Accomplishments by Project Goal

1. Examine the primary cropping systems, water availability, and irrigation systems on native American reservations in Utah.
Data set completed and used in Goal 2 below.
2. Evaluate the potential economic feasibility of alternative cropping systems including low water-use, heat resistant, high CO2 resistant marketable crops and high-value crops on reservations.
One journal article was drafted and one more will be written in 2023.
Three Extension factsheets will be written and submitted in 2023.
3. Evaluate the potential economic feasibility of ag-related enterprises (food product development, food tourism, etc.) on reservations.
One journal article was published in 2022.
4. Assess the economic, social, and cultural benefits and impediments to producer adoption of management strategies/alternative cropping systems and ag-related enterprises.
One journal article was published in 2022.
5. Assess educational and technical assistance needs.
Started as part of Goals 2 and 4 above.
6. Disseminate study results and information to agricultural producers and policy makers on reservations.
See Dissemination below.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Agricultural producers and policy makers in Tribal communities in and adjacent to Utah.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

One post-doctoral fellowship in progress.

Dissemination:

All project outputs were posted to the project website at: <https://extension.usu.edu/apec/tribalagricultureanddrought>. The website and associated publications had 1131 views in 2022.

Project outputs were also posted on the Native Waters – Arid Lands project website at: <https://nativewaters-aridlands.com/resources/tribal-agriculture-drought/>

Extension Factsheets published under this project have been viewed 849 times since publication.

Journal articles published under this project in 2021-22 have been cited 6 times.

Products:

Publications:

Refereed Journal Articles:

Drugova, T., Curtis, K., & Kim, M.-K. (2022, September 30). The Impacts of Drought on Southwest Tribal Economies. *Journal of American Water Resources Association*, 58(5), 639-653.

Drugova, T., Curtis, K., & Ward, R. A. (2022, January). Producer Preferences for Drought Management Strategies in the Arid West. *Renewable Agriculture and Food Systems*, 37, 14-23.

Plan of Work:

Plan of Work by Project Goal

1. Examine the primary cropping systems, water availability, and irrigation systems on native American reservations in Utah. Completed.

2. Evaluate the potential economic feasibility of alternative cropping systems including low water-use, heat resistant, high CO2 resistant marketable crops and high-value crops on reservations.

Submit drafted journal article, draft additional article and three fact sheets.

3. Evaluate the potential economic feasibility of ag-related enterprises (food product development, food tourism, etc.) on reservations. Completed.

4. Assess the economic, social, and cultural benefits and impediments to producer adoption of management strategies/alternative cropping systems and ag-related enterprises.

Continue to publish one journal article currently under review (R&R).

5. Assess educational and technical assistance needs.

Continue assessment

6. Disseminate study results and information to agricultural producers and policy makers on reservations.

Present results from Goals 1-4 at national, regional, and state producer meetings and Indian agricultural conferences.

Create outreach materials for use with target audience.

Continue project impact assessment and draft assessment tools.

How do climate and phenology structure the contact patterns associated with disease transmission in a free-ranging ungulate?

Project Director

Kezia Manlove

Organization

Utah State University

Accession Number

1018794



How do climate and phenology structure the contact patterns associated with disease transmission in a free-ranging ungulate?

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall goal of the project is to understand how contact and mixing dynamics vary with climate-related factors, and to document whether that variation corresponds to disease severity and epidemic spread.

Aim 1: Characterize and contrast patterns of survival and clinical signs displayed by adult bighorns following a low- and a high-severity *M. ovipneumoniae* introduction event, and relate these contact patterns (along with those collected across the suite of study herds) to environmental variables.

Aim 2: Document and compare patterns of survival and clinical signs displayed by bighorn lambs following a low- and a high-severity *M. ovipneumoniae* strain.

Aim 3: Conduct baseline profiling of group mixing dynamics within the Zion National Park (ZNP) and National Bison Range (NBR) bighorn herds to characterize how birth pulse structure relates to formation of nursery groups, and interactions within those groups. Then, extend this analysis to incorporate the rest of the focal herd suite, and determine relationships between group mixing and environmental variables.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

We continued to monitor our Zion, National Bison Range, and Southern Nevada field sites in collaboration with the National Park Service, Utah Division of Wildlife Resources (UDWR), and the USGS. We expanded our Zion efforts to include both bighorn sheep and mule deer. A new Master's student, Ian Montgomery, began a project supported in part by Utah Division of Wildlife Resources and Zion Forever, and we used some UAES project resources to facilitate field data collection for that project (which examines forage and apparent competition between bighorn sheep and mule deer). Two master's theses (Grete Wilson-Henjum's and Toni Proescholdt's) were completed and two additional theses are in preparation using support from this project. We anticipate submission of several thesis chapters associated with this project early next year. Collectively, we have gathered more than 500 direct observations of bighorn sheep as part of this project, and have coded over 10,000 photographs. We have completed the spatial and camera analyses from southern Nevada (completed MS thesis #1) and the social analysis from the Bison Range (completed MS thesis #2).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Zion National Park, Desert National Wildlife Refuge, Confederated Salish and Kootenai Tribes, Lake Mead National Recreation Area, Utah Division of Wildlife Resources, Nevada Department of Wildlife, USGS

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

We have some turnover in personnel this year, with two master's students defending and one new student coming on. The project has not encountered any major problems. New work in our group on SARS-CoV-2 in mule deer has opened the door for gathering gene transcription samples that might offer new insights into drought effects on ungulates. Because these samples prioritize mule deer, we may shift field observation emphasis to that species more this year than we have in the past.

Training and Professional Development:

Four master's students have been trained or are currently being trained using resources provided in part by this project. In addition to providing field support to all four projects, the resources from this UAES grant supported time for the PI to train eleven Utah State University (USU) graduate students in big game disease surveillance and behavioral protocols; augment data collection in the National Bison Range, Southern Nevada, and Zion field systems; and develop camera data at the southern Nevada research sites.

Dissemination:

The PI presented project updates at: the Utah chapter of The Wildlife Society; the Northern Wild Sheep and Goat Council, and directly to Utah Division of Wildlife Resources personnel in their invited brownbag lunch series. Graduate students Grete Wilson-Henjum and Toni Proescholdt presented findings from the Southern Nevada project and the Bison Range project respectively at the Northern Wild Sheep and Goat Council. Manlove and Wilson-Henjum completed their collaboration with the Desert National Wildlife Refuge to apply Wilson-Henjum's water-related field results for bighorn sheep monitoring on both DNWR and adjacent Department of Defense lands. We completed our final report with all data analysis to date on the first stage of the Zion bighorn project. Wilson-Henjum and Proescholdt both delivered public talks as part of their thesis defenses.

Products:

Presentations:

Manlove, K., Ecological Society of America Annual Meeting, "Spatial and social drivers of movement along a latitudinal and life-history cline," Ecological Society of America, Remote. (August 8, 2021 - Present)

Wilson-Henjum, G. (Presenter & Author), Longshore, K. (Author Only), Manlove, K., 56th Meeting of the Desert Bighorn Council, "Assessing the ability of guzzler trail cameras to estimate desert bighorn sheep population size and recruitment rate," Desert Bighorn Council, Remote. (April 4, 2021 - Present)

Sinclair, K. (Presenter & Author), Cox, M. (Author Only), Manlove, K., Biennial Symposium of the Northern Wild Sheep and Goat Council, "Identifying drivers of bighorn sheep population recovery in the wake of pneumonia die-off events," Wild Sheep Foundation, Remote. (November 5, 2020 - Present)

Johnson, B. (Presenter & Author), Stroud-Settles, J. (Author Only), Roug, A. (Author Only), Manlove, K., Biennial Symposium of the Northern Wild Sheep and Goat Council, "Symptom progression and serological dynamics following introduction of a low-virulence *Mycoplasma ovipneumoniae* strain in a desert bighorn herd," Wild Sheep Foundation, Remote. (November 5, 2020 - Present)

Other Products:

Data and Research Materials We completed our analysis of movements in the southern Nevada sites via water guzzlers. We generated functional relationships between statistical bias in trail camera detection of animals and habitat features. The PI conducted an analysis of habitat selection over the course of the year across a latitudinal cline using a Nevada-wide dataset and found strong support for water as an aggregating feature in parts of the bighorn range. This helped to crystallize the mechanistic questions we aim to address in the UAES project (we are focusing on mechanisms associated with social learning and queuing: what triggers or impedes individual use of water at the various sites, and how does the spatial pattern of water

availability shape group stability patterns). We continued monitoring the *Mycoplasma ovipneumoniae* strain circulating in the Zion bighorn sheep herd, but that strain appears to have faded out. A gap in juvenile survival and continued population declines have motivated additional inquiry into the role of drought in nutrition within that system. To that end, we began directly monitoring what food sources bighorn sheep rely upon in Zion during the summer months. Additional support from UDWR and ZNP have augmented the UAES resources for this project, and will allow us to continue monitoring the Zion herd through 2024.

Databases - We have cleaned and organized the long-term bighorn sheep database from the Bison Range (this effort included digitizing over 500 paper maps, which will allow us to explore spatial dynamics within this system in much more detail going forward).

Plan of Work:

In 2023, we will continue gathering diet data at Zion National Park, and we will take steps to expand this effort to other parts of the state. We have augmented existing data with a new datastream: gene transcription data acquired during bighorn sheep and mule deer captures throughout this fall. While these samples are not yet developed, we will seek funding to develop them. The samples are longitudinal (we anticipate sampling each animal four times, once in fall and once in spring), and might therefore be able to provide us with novel insights into the physiological mechanisms that govern drought effects on ungulates. Samples were gathered during capture efforts tied to another project in our lab. Field seasons for the Zion project will continue to run from ~Feb-July, and for the Bison Range Project from mid-April to mid-July. Data collection priorities will focus on our long-term datasets, but we will augment data collection to target project-specific questions including diet data more intensively this year.

Closing Out (end date 06/12/2024)

Maintaining Resilient Sagebrush & Rural Communities

Project Director

Eric Thacker

Organization

Utah State University

Accession Number

1018723



W1188: Maintaining Resilient Sagebrush & Rural Communities

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1) Prioritize threats to sagebrush systems and construct a prioritization framework.

Comments: Threats to sagebrush systems result in a loss of ecosystem services for dependent species and local communities throughout the West. We synthesized existing threat frameworks from organizations involved in sagebrush ecosystem conservation, focusing on threats to the sagebrush system and dependent species. Natural variation in the ecology of the sagebrush biome influences type and intensity of the threats. Sagebrush Ecosystem Threats Framework: • Invasive Weeds/Grass and Wildfire • Sagebrush Alteration • Cultivation • Sagebrush Removal • Loss of Mesic Areas • Conifer Expansion • Human Use & Development • Energy Extraction • Urban Development • Mining • Recreation • Improper Grazing • Inappropriate Livestock Grazing • Free-Roaming Equids Our sub-objectives are to: 1.1. Combine existing data from multiple institutions to enhance collaboration improving inference on social/ecological issues, 1.2. Integrate socio-ecological sciences to assess consequences of threats (real and perceived), 1.3. Prioritize and compare threats by ecological and social frameworks, 1.4. Evaluate the socio-ecological outcomes of threat reduction, 1.5. Develop a framework to resolve differences in ecological and social threat prioritization, 1.6. Create a common data collection framework to facilitate regional assessment.

2) Evaluate links between land management and health of rural communities in the sagebrush biome.

Comments: A perception in many rural communities is that the conservation of threatened and endangered species does not adequately consider the impact on local land use or economies (Public Lands Council, 2017). An example of such conflict is the Bureau of Land Management (BLM) Land Use Plans (LUPs) developed in response to proposed listing of greater sage-grouse. Recently, collaborative groups have arisen in several locations to provide input on land management decisions. Many social and economic forces are transforming the economies and structure of rural communities in the West such as mineral

and energy extraction. The economic impacts of federal management decisions regarding natural resources significantly influence the businesses and individuals in the surrounding communities. These linkages mean that resource production generates jobs and income not only in the agriculture sector but also in other sectors in the local economy that support natural resource sector or serve employee households. Previous studies have failed to implement integrated approaches that contextualize social behaviors and attitudes within social-ecological systems as complex adaptive systems. We seek to: 2.1 Understand the dynamics of economic drivers upon conservation and socioeconomic communities, 2.2 Identify the means to build social and ecological capital to enable effective conservation of sagebrush and rural communities, 2.3 Evaluate the effectiveness of collaboration and local working groups in these processes.

3) Engage local communities in research and outreach.

Comments: Engagement implies a dialogue between researchers and stakeholders. Results from integrated research on threats and consequences to sagebrush and human communities and the links between sagebrush land management and the health of rural communities must be communicated to key stakeholders to be meaningful. In addition, listening to those stakeholders on their concerns, issues, solutions, and alternatives will inform researchers as to the important questions to address. In both cases, education about science, values, and culture will occur in all directions. Our sub-objectives are to: 3.1. Provide land and wildlife management agencies with factsheets and presentation that summarize the relationship between ecological outcomes of land management actions to socio-economic consequences. 3.2. Produce outreach materials that clearly communicate how the ecological threats to sagebrush systems can have impacts on local and state socio-economic.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The W1188 successfully applied and received funding from USDA-AFRI NIFA for a proposal titled “*Sustaining rural livelihoods, livestock grazing, and sage-grouse habitat in western sagebrush systems*” (\$650,000) and was awarded through University Nevada-Reno, with Perry Williams as Lead Investigator. Two proposals were submitted to the National Science Foundation 1) “*Socioeconomic Resilience and Transformation in the New Rural West-the Convergence of Energy Development, Exurban Development, and Climate Change*”.NSF-DISES for \$1.6 mill submitted through Montana State University, with Lance McNew, as lead investigator, and 2) “*Developing Transferability and Fluency in a Transdisciplinary Effort to Disentangle Socioeconomic-Ecological Resilience in the Sagebrush Biome*” NSF-MCA (\$250,000) was submitted by Christian Hagen, Oregon State University, with JD Wulforst and Katherine Lee University of Idaho, as co-investigators and as host institution for Hagen’s activities.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Land managers, livestock producers and academics working in sagebrush systems.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

N/A

Training and Professional Development:

Nothing to report.

Dissemination:

Plan of Work:

The human and economic dimensions of sagebrush communities have an unprecedented scope, and there is a need for resilience-based management of the sagebrush biome. Our approach will provide a holistic view of agroecosystem sustainability as it pertains to quantifiable economics related to livestock production, energy development and qualitative sociological components such as sense of place, community security, and anxiety from contemporary threats of climate change.

In addition to improving our basic understanding of rural SESSs, our project will address critical knowledge gaps in resource dependent rural communities for community corridors in our study area, which allows for testing specific hypotheses about the correlations and dynamics between socio-economic, ecological resilience, and ecosystem health. Policy initiatives such as President Biden's 30x30 conservation plan and transition to renewable energy necessitates understanding how these changes may affect resource dependent rural communities. The structure of our models, from micro (livestock production) to macro (regional development model) scale, will inform a vector of socioeconomic resilience measures that will be linked directly to ecosystem health (sage-grouse populations). This approach will allow for variation in environmental socio-economic inputs and assumptions to represent key attributes of rural communities.

Our proposed work will assist in informing resource dependent communities in planning and negotiating with and between multiple institutions, private landowners and resource managers in the western United States. As mentioned above, the sagebrush biome is exposed to several stressors due to climate change, invasive species, and human development, all of which also affect human dimensions. It is our hope that this work will contribute significantly to improving delivery of conservation actions that will mutually benefit rural communities, the ecosystem, and wildlife therein.

The models developed in this project will be part of the tools and information needed for ranchers, agency personnel, and local policymakers to make better and more secure decisions about future economic growth. Students and faculty will work with agencies and local citizen representatives to use the decision support systems to create more economically and socially resilient communities. Scientists will have a better sense of how local residents think about the environment around them and the science that is produced. The framework proposed here will be transferable to other biomes that share natural resource based economies. The multi-attribute decision model will provide a framework to serve as a decision tool for planners and scientists alike to assess socio-ecological interactions and outcomes both in a planning sense but also as a management tool that can serve adaptive management in intervening years

Select Stress Tolerant Plants and Promote the use of Native Plants for Water Efficient Landscape

Project Director

Youping Sun

Organization

Utah State University

Accession Number

1015062



Select Stress Tolerant Plants and Promote the use of Native Plants for Water Efficient Landscape

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overarching objectives of this project are: 1) to enhance the understanding of the whole-plant response of woody and herbaceous plants to natural or managed water stress in urban landscapes; 2) to provide practical recommendations on the use of plant species for water-efficient landscaping, and 3) to promote the use of native plants for water-efficient landscaping through the development of sustainable culture practices and efficient propagation protocols.

These broad objective will be achieved through the following sub-objectives:

- A). Evaluate the drought tolerance of landscape plants that are commonly used in Utah and the Intermountain West,
- B). Evaluate the salt tolerance of landscape plants that are commonly used in Utah and the Intermountain West,

C). Establish efficient vegetative propagation methods or micro-propagation protocols for developed superior cultivars or selections of native plants,
D). To determine the nutrient and water requirements of developed superior cultivars or selections of native plants for water-efficient landscapes.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective A: Evaluate landscape plants for drought tolerance.

A-I: A total of 26 ornamental grass and grass-like species/cultivars were planted in 2018 in Utah Agricultural Experiment Station's Greenville Research Farm following a randomized complete block design. Plant growth and performance were recorded in 2019, 2020, and 2021, in order to select suitable ornamental grasses for landscape use in Utah and the Intermountain West, one of the driest and fastest growing regions in the United States.

A-II: Thirty newly developed landscape plant species/cultivars (720 plants total) have been transplanted to USU's Greenville Research Farm. For the first field trial plot established in May 2021, 456 plants (19 species/cultivars) were irrigated at 80% of reference evapotranspiration (ET_o) throughout summer 2021 for establishment. These plants are being evaluated with three deficit irrigation treatments representing 80%, 50%, and 20% of ET_o in 2022 and 2023. Visual quality and plant growth and physiology data are currently collected. For the second plot established in May 2022, 264 plants (11 species/cultivars) are currently irrigated at 80% of ET_o throughout summer 2022 for establishment. These plants will be evaluated with three deficit irrigation treatments in 2023-2024. Low water use landscape plants will be identified for use in Utah and the Intermountain West.

A-III: Two greenhouse experiments (October 2020 – January 2021; November 2021 – March 2022) have been conducted to evaluate the effects of substrate volumetric water contents on the growth and development of *Shepherdia ×utahensis* 'Torrey' and *Penstemon barbatus* 'Novapenblu', *Penstemon X mexicali* 'P007S', *Penstemon digitalis* 'TNPENDB'. This research helped understand the morphological and physiological responses of landscape plants to varying substrate volumetric water contents maintained using a sensor-controlled automatic irrigation system in a controlled environment.

Objective B: Evaluate landscape plants for salt tolerance.

B-I: Eleven greenhouse experiments have been conducted to evaluate ornamental plants for salinity tolerance and to characterize the morphological and physiological responses of ornamental plants to salinity stresses. A total of 63 plant species/cultivars (ornamental grasses, spirea, viburnum, Sego Supreme™ plants, ninebark, rose of Sharon, penstemon, mimosa, Japanese pagoda tree, Utah native plants) have been evaluated. A wide range of salinity tolerance was found among tested species and/or cultivars, and salt-tolerant plants selected for use in salt-prone areas or where low-quality irrigation water is being used.

1. Experiments with treatments (nutrient solution at an electrical conductivity (EC) of 1.2 dS/m-1 (control) or saline solutions at EC of 5.0 or 10.0 dS/m-1):

1) October 2017 – March 2018: *Bouteloua gracilis* (blue grama), *Chasmanthium latifolium* (Indian seaoats), *Leymus arenarius* 'Blue Dune' (sand ryegrass), *Muhlenbergia capillaris* (pink muhly grass), and *Pennisetum alopecuroides* 'Foxtrot' (fountain grass), *Carex vulpinoidea* (fox sedge), and *Juncus effusus* (common rush).

2) April 2018 – June 2018: *Eragrostis spectabilis* (purple love grass), *Miscanthus sinensis* 'Gracillimus' (maiden grass), *Panicum virgatum* 'Northwind' (switchgrass), and *Schizachyrium scoparium* (little bluestem).

3) February 2019 – May 2019: *Viburnum ×burkwoodii*, *V. cassinoides* 'SMVCDD', *V. dentatum* 'Christom', *V. dentatum* var. *deamii* 'SMVDBS', *V. dilatatum* 'Henneke', *V. ×NCVX1*, *V. nudum* 'Bulk', *V. opulus* 'Roseum', *V. plicatum* var. *tomentosum* 'Summer Snowflake', *V. pragnae* 'Decker', *V. ×rhytidophylloides* 'Redell', and *V. trilobum* (viburnum).

4) June 2019 – November 2019: *Acorus gramineus* (Japanese rush), *Andropogon ternarius* (silver bluestem), *Calamagrostis ×acutiflora* (feather reed grass), *Carex morrowii* (Japanese sedge), *Festuca glauca* (blue fescue), *Sporobolus heterolepis* (prairie dropseed), *Pennisetum alopecuroides* (fountain grass) and *Cymbopogon Citratus* (West Indian lemon grass).

5) August 2020 – September 2020: *Albizia julibrissin* (mimosa), *Robinia pseudoacacia* (black locust), *Sophora japonica* (Japanese pagoda tree), and *Gleditsia triacanthos* (honey locust).

6) March 2021 to May 2021: *Albizia julibrissin*, *Robinia pseudoacacia*, *Sophora japonica*, and *Gleditsia triacanthos*.

7) August 2021 to October 2021: *Amelanchier pumila* (serviceberry), *Arctostaphylos uva-ursi* (kinnikinnick), *Ceanothus prostratus* (prostrate ceanothus), *Ceanothus velutinus* (snowbrush ceanothus), *Cercocarpus montanus* 'Coy' (alder-leaf mountain-mahogany), *Cercocarpus ledifolius* (curl-leaf mountain mahogany), *Shepherdia ×utahensis* 'Torrey' (hybrid buffaloberry).

2. Experiments with treatments (nutrient solution at an EC of 1.2 dS·m⁻¹ (control) or saline solutions at EC of 3.0 or 6.0 dS·m⁻¹):

1) March 2018 – June 2018: *Spiraea japonica* (Japanese spirea) 'Artisan', 'Big Bang', 'Candy Corn', 'Doozie', 'Gold', 'Painted Lady', 'Pink', and 'Red'; *Spiraea betulifolia* 'Tor Gold', *S. media* 'SMSMBK', *S. nipponica* 'SMNSNFD', and *S. thunbergia* 'Ogon'.

3. Experiments with treatments (nutrient solution at an EC of 1.25 dS·m⁻¹ (control) or saline solution at an EC of 2.5, 5.0, 7.5, or 10.0 dS·m⁻¹):

1) August 2018 – December 2018: Sego Supreme™ plants [*Aquilegia barnebyi* (oil shale columbine), *Clematis fruticosa* (Mongolian gold clematis), *Epilobium septentrionale* (northern willowherb), and *Tetranneuris acaulis* ~~arizonica~~ *arizonica* (Arizona four-nerve daisy)].

4. Experiments with treatments (eight EC levels ranging from 0.8 to 6.4 dS·m⁻¹ in 2018-2019 or 1.0 to 6.7 dS·m⁻¹ in 2019-2020):

1) July 2018 – January 2019: *Hibiscus syriacus* (rose of sharon), *Physocarpus opulifolius* (ninebark), and *Spiraea japonica* (Japanese spirea).

2) November 2019 to February 2020: *Penstemon barbatus* (golden beard penstemon) and *Penstemon strictus* (beardtongue).

Objective C: Developing efficient propagation protocols for native plants.

C-I: *Cercocarpus montanus* and *Ceanothus velutinus* were evaluated for Stage I (establishment), Stage II (shoot multiplication), and Stage IV (root formation) to produce efficient micropropagation protocols.

C-II: Cutting propagation of *Cercocarpus montanus* and *Ceanothus velutinus* were conducted to test the effects of wounding, different plant growth regulators, and timing for cutting collection on root formation.

C-III: A total of 1423 grafts were conducted using *Pinus edulis* (two-needle pinyon pine) seedlings as rootstocks and *Pinus monophylla* (single-needle pinyon pine) scionwoods collected from Raft River, ID, in 2020 (651 grafts), 2021 (634 grafts), and 2022 (138 grafts). About 720 grafted pinyon pines are available for field trials for nut production. In June 2022, we established two field plots in St. George and Blue Creek, UT with 360 grafted pinyon pine trees.

C-IV: Nodulation was achieved for *Shepherdia ×utahensis* 'Torrey' and *Ceanothus velutinus*. Rooted cuttings of *Shepherdia ×utahensis* 'Torrey' were inoculated with soils collected from a plant in USU's Greenville Research Farm, while seedlings of *Ceanothus velutinus* with native soils collected from Tony Grove. Plants were grown in cone-shaped containers containing Metro-Mix® 820 substrate, perlite, or calcined clay and inoculated with 30 ml of soils. Nitrogen-free nutrient solution was applied to plants. Plants were harvested to check for nodules every two weeks after establishment. Both plant species formed nodules 3 month after inoculation.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

- This project has advanced our knowledge regarding the responses of whole plants to water stresses, including drought and salinity, which facilitates the utilization of drought-resilient and salt-tolerant plants for water conservation.

- This project has also improved the vegetative propagation of native plants and developed sustainable production practices, which aids in promoting the use of native plants for water-efficient landscaping.
- Information generated from this project ultimately benefits the water conservation efforts of the green industry, sustains the environment, and contributes to the body of scientific knowledge.

Briefly describe how the broader public benefited from your project's activities.

- This project has advanced our knowledge regarding the responses of whole plants to water stresses, including drought and salinity, which facilitates the utilization of drought-resilient and salt-tolerant plants for water conservation.
- This project has also improved the vegetative propagation of native plants and developed sustainable production practices, which aids in promoting the use of native plants for water-efficient landscaping.
- Information generated from this project ultimately benefits the water conservation efforts of the green industry, sustains the environment, and contributes to the body of scientific knowledge.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems: Nothing to report.

Training and Professional Development:

Advancing Mentoring Workshop, USU's College of Agriculture and Applied Sciences, Logan, UT, 1:00-3:30 pm, 19 and 26, January 2022. Organizer and Presenters: Drs. Abby D. Benninghoff, Brent Chamberlain, Heloisa Rutigliano, and Elizabeth Vargis.

Teaching Documentation Workshop, USU's Provost's Office, Logan, UT, 8:00-4:30 pm, 10-13 May 2022. Mentor: Dr. Cathy Ferrand Bullock, Department of Journalism and Communication, USU, Logan, UT.

Dissemination:

Six peer-reviewed papers were published to disseminate research results to scientific community.

1) Paudel, A. and Y. Sun. 2022. Growth, gas exchange, and mineral nutrients of two popular landscape plants irrigated with saline water. *HortScience* 57(8):841-850.

2) Paudel, A., Y. Sun, L.A. Rupp, J.G. Carman, and S.L. Love. 2022. Vegetative propagation of *Ceanothus velutinus* using stem cuttings. *Native Plant Journal* 23(1): 123-129.

3) Chen, J., Y. Sun, K. Kopp, L. Oki, S.B. Jones, and L. Hipps. 2022. Effects of water availability on leaf trichome density and plant growth and development of *Shepherdia xutahensis* 'Torrey'. *Frontiers in Plant Science*. 13:1-14.

4) Sun, Y., G. Niu, H. Dou, C. Perez, and L. Alexander. 2022. Growth, gas exchange, and mineral nutrients of hydrangea hybrids irrigated with saline water. *HortScience* 57(2): 319-325.

5) Lawson, K.C., L.A. Rupp, Y. Sun, and R. Newhall. 2021. Propagation of pinyon pine: Topworking *Pinus monophylla* to *Pinus edulis* rootstocks. *Native Plants Journal* 22(3): 280-292.

6) Lawson, K.C., L.A. Rupp, Y. Sun, R. Newhall, and C. Reid. 2021. Propagating selected *Pinus monophylla* accessions by grafting to *Pinus edulis* seedling rootstocks. *Native Plants Journal* 22(3): 293-305.

Four conference abstracts have been accepted and will be published to disseminate research results to scientific community.

- 1) Chen, J., Y. Sun, and K. Kopp. 2022. Detecting drought stress of penstemons using infrared thermal imaging. HortScience 57(9): Sxxx-xxx.
- 2) Chen, J., J. Mathews, A. Paudel, and Y. Sun. 2022. Field trials of 26 ornamental grass and grass-like plants. HortScience 57(9): Sxxx-xxx.
- 3) Paudel, A., M. Sanders, and Y. Sun. 2022. Nodulation of *Ceanothus velutinus*. HortScience 57(9): Sxxx-xxx.
- 4) Paudel, A. and Y. Sun. 2022. Responses of Utah native plants to saline water irrigation. HortScience 57(9): Sxxx-xxx.

Three presentations were made to disseminate research results to academic community and county agents.

1. Sun, Y. 2022. Alternative Plants for Fruit and Nut Production on Marginal Lands. Guest Lecture for HORT 3213: Fruit and Nut Production (Dr. Lu Zhang), Department of Horticulture & Landscape Architecture, Oklahoma State University, 28 March 2022.
2. Paudel, A. and Y. Sun. 2022. Response of Utah native plants to saline water irrigation. USU Student Research Symposium, Utah State University, Logan, UT, 15 April 2022.
3. Sun, Y., R. Wytsalucy, and B. Scow. 2022. Establishing pinyon pine orchards for nut production on marginal lands. 2022 Extension Annual Conference, Thanksgiving Point, Lehi, UT, 3 March 2022.

Plan of Work:

Objective A: Thirty newly developed landscape plant species/cultivars (720 plants total) have been transplanted to the USU's Greenville Research Farm. For the first field trial plot established in May 2021, 456 plants (19 species/cultivars) were irrigated at 80% of reference evapotranspiration (ET_o) throughout summer 2021 for establishment. These plants are being evaluated with three deficit irrigation treatments representing 80%, 50%, and 20% of ET_o in 2022 and 2023. Visual quality and plant growth and physiology data are currently collected. For the second plot established in May 2022, 264 plants (11 species/cultivars) are currently irrigated at 80% of ET_o throughout summer 2022 for establishment. These plants will be evaluated with three deficit irrigation treatments in 2023-2024. Low water use landscape plants will be identified for use in Utah and the Intermountain West.

Objective B: Complete the experiment on *Penstemon barbatus* and *Penstemon strictus* with treatments (nutrient solution at an EC of 1.25 dS·m⁻¹ (control) or saline solution at an EC of 2.5, 5.0, 7.5, or 10.0 dS·m⁻¹) initiated in May 2022.

Objective C: Grafted pinyon pines transplanted to Hurricane Valley Fruit Farms and UAES Blue Creek Research Farm will be evaluated in the years to come (8-10 years).

This is the FINAL report for this project.

Leveraging the NADP network to fill critical dust deposition data and knowledge gaps

Project Director

Janice Brahney

Organization

Utah State University

Accession Number

1015140



Leveraging the NADP network to fill critical dust deposition data and knowledge gaps

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Our overarching hypothesis is that biogeoclimate and land-use affect emission rates and composition of dust, which in turn influence a) aquatic ecosystems, and b) human health. Ecosystem impacts have been demonstrated by our previous work that showed a high degree of correlation between deposition and lake water chemistry (Brahney et al. 2014, 2015a, 2015b), and data from 1000's of waterbodies across the country that indicate phosphorus concentrations are increasing in remote locations (Figure 2; Stoddard et al. 2016). Public health impacts are supported by findings of the Center for Disease Control that incidents of Valley Fever, contracted by inhaling soil borne-pathogens, are increasing in the southern states (CDC 2013). Further, drought has been linked to the production and transport of aeroallergens and irritants (Takaro et al. 2013), and studies in the Middle East have showed cyanotoxin persistence in eroded soils (Richer et al. 2015) that may be linked to a variety of diseases (Takser et al. 2016). By measuring total mass of deposition at a high spatiotemporal resolution, we can quantify ecosystem impacts across different aquatic environments, determine potential human exposure to pathogens, and identify prominent dust producing areas. We plan to test our central hypothesis by pursuing the following two specific objectives:

Objective 1: Demonstrate that deposition of the full range of dust can be implemented at a regional scale by using novel deposition samplers deployed at existing NADP stations. We hypothesize that variation in dust deposition and composition is driven by biogeoclimate and land-use activity across space. We will use a combination of back trajectory models and genomic and isotopic signatures to trace unique regional sources and identify where dust originates.

Objective 2: Determine direct ecological impacts of dust deposition on lake ecosystems. Our working hypothesis is that variation in dust composition and deposition input rates affect nutrient availability, species composition, and productivity of plankton in recipient lakes. To test this hypothesis, we will perform leaching experiments and bioassays using dust collected from Objective 1 to quantify bioavailability of dust-derived nutrients.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

At present, there are nearly 30 sites fully operational across the western USA with contiguous data. To date, over 800 dust samples have been collected, and an additional 60 dust samples have been acquired from NEON. All dust samples have been weighed, processed, and stored in temperature-controlled environments at Utah State University. Non-destructive analyses are being performed in advance of destructive techniques on both samples collected through this study and NEON samples.

To date, mass deposition rates and plastic content have been completed for both years, while pH, metal chemistry, extractable phosphorus and nitrogen, and bioassays have been completed for year 1 and are in progress for year 2. We added a new metric, charcoal concentration, due to the unprecedented fire years in the western USA over the past two summers. Ash often contains higher concentrations of bioavailable phosphorus, and is thus relevant to our goals. Experiments at three lakes chosen for bioassay studies have been completed, including Castle Lake, CA, the Loch, CO, and Flathead Lake. Controlled laboratory bioassays assessing algal responses to dust as well as pH and temperature have been completed. With respect to source attribution, air mass back trajectory data is being generated and smoke data layers are being used to establish fire contribution to particulate deposition.

Dust microbial analyses began in the Fall of 2020. DNA extraction procedures have been tested to determine minimum dust sample requirements. BacLight viability and flow cytometry methods have been finalized to determine the number of viable organisms within each sample. Despite establishing the techniques, a wide range of samples have not yet been analyzed at BYU and we anticipate these results in the coming year. In a preliminary subset of sites (five), we found the relative frequency of microbial species varied substantively.

Due to the global pandemic, we took the opportunity to measure particulate samples for SARS-CoV-2.

Our results to date have identified a seasonality in both total mass deposition rates as well as dust composition. As we hypothesized, dust deposition rates increase through the spring at most sites but reach their peak during the summer months. The 2020-2021 dust year was substantively higher than the preceding years. These patterns are repeated at all field sites with multiple years of data. Higher summer deposition suggests that annual dust deposition rates may be frequently underestimated since one of the most common methods for estimating annual dust deposition rates is through dust on snow collection. Dust deposition rates vary by an order of magnitude across the American west (Figure 1) Synchronized with changes in mass deposition rates are significant changes in dust composition. Through the summer, dust carbon isotopes are largely consistent with organic matter from soil and vegetation sources. At least one Arizona sample is a clear outlier with carbon isotopes closer to values consistent with C4 desert grasses. Through the cooler months, $\delta^{13}\text{C}$ values

migrate towards more depleted isotopic values more consistent with atmospheric methane and perhaps other yet unidentified sources. Nitrogen isotopes (not shown) also show seasonal signals reflecting shifting atmospheric aerosol sources. Dust pH is markedly lower and more acidic in winter months and trend towards more alkaline values in the mid-summer. Of particular relevance to this study are the distinct seasonal changes in phosphorus concentrations as measured by XRF, which dip to the lowest values in the winter months. Lower winter P concentrations combined with dust-on-snow based deposition rates suggest that previous estimates of P deposition may be considerably underestimated

Total phosphorus deposition rates ranged from 4 to 60 mg m⁻² yr⁻¹. Bioavailability ranged from 37 to 70% (Figure 2). Bioavailability was greater in the winter months for arid regions, but greater during the summer for semi-arid and mountain landscapes. Preliminarily, bioavailability appears to vary with organic content in the summer and combustion sources in the winter. Here we define the bioavailable fraction as the water-soluble plus exchangeable plus the organic fraction of the NaOH extract. Given an average wet plus dry dust deposition rate at UT95 (the East McKee site) of 10.13 g m⁻² year⁻¹ and a bioavailable P concentration of 1.09 mg g⁻¹ of dust, we arrive at a bioavailable P deposition rate of 11 mg P m⁻² year⁻¹. This is potentially an underestimate given the higher P concentrations observed through the summer. Nevertheless, for a lake that is 0.5 km² in area with an epilimnion depth between 5 and 10 m, direct dust deposition to the lake surface could account for a 1.1-2.2 ug P L⁻¹ increase in water column nutrients. This approximation does not account for catchment focussing; Though not yet evaluated for our field stations, previous work has shown that up to 30% of the dust deposited to a catchment could end up with the lake basin (Brahney et al. 2015). These back-of-the-envelope calculations indicated that dust could be a significant driver of ecosystem change, which we have tested through field and laboratory bioassays. Finally, we found a significant positive relationship between charcoal concentration and phosphorus deposition rates, and bioavailability (Figure 3).

An additional interesting and somewhat unexpected result is the positive association of organic matter, total phosphorus, and bioavailable/organic phosphorus content with elevation (Figure 4), perhaps reflecting a shift in aerosol size fractions with elevation. This hypothesis is yet to be tested and grain size analyses should provide some insights.

Field bioassays have shown a positive relationship between dust additions and chlorophyll-a content, but a negative relationship to net primary production (Figure 5). At Castle Lake, significant differences in final chlorophyll-a concentration were observed across all treatments, through the lowest dust addition was not markedly different from the control. However, in vivo fluorescence showed statistically significant differences between the control and the lowest dust deposition as the lowest dust treatment showed a positive slope while the control did not (Figure 5). We hypothesize that the contrast between chlorophyll concentration and primary production is a result of low dust additions stimulating large phytoplankton species, while higher dust treatments stimulate smaller-sized phytoplankton. A negative relationship between production and the relative contribution of small cells exists, supporting this notion. This hypothesis will be further tested in this upcoming year through community composition and size distribution analyses of the preserved bioassay samples. Laboratory assays have revealed a strong positive relationship between dust additions and the planktonic growth rate of a single species (*Scenedesmus obliquus*). The results were moderated by the initial condition, including pH and temperature. Lower pH and high temperatures led to a greater effect of dust on the phytoplankton growth rate, suggesting that in the future the effect of dust deposition on lake systems may be amplified. Subsequent analyses will examine the effect of dust additions and pH on the stoichiometry of algal cells. With respect to microbial community composition, we found substantive differences in the operational taxonomic units between five samples collected at four sites. These results suggest that dust source controls microbial community composition (Figure 6).

Three NSF grants have been funded through based on the initial UAES proposal including one Macrosystem Biology grant, Critical Zone Network, and a second 5-yr Macrosystem Biology grant (to begin Fall 2022). In addition several grants through the USFS Forest Service were also supported.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

- The Network Operations Subcommittee and the Joint Subcommittees of the National Atmospheric Deposition Program
- The general public
- The scientific community

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

COVID-19 Delays: The onset of the COVID-19 pandemic shortly after the inception of the study has created some unforeseen and new challenges. With respect to student activities, there has been limited or restricted access to laboratories within USU and external labs and the international PhD student involved was unable to acquire a drivers license through the summer period as local facilities were closed. The establishment of sites has been slowed and significantly delayed as the engineering facility that produces the samplers (and the external manufacturers of parts) have undergone intermittent closure. The organization was shut down entirely for a period of time as the workers in the facility contracted COVID-19. As a result, only a small portion of our requested samplers have been delivered to date. This lack of samplers has limited the spatial scope of the study but has not impacted the data generated from the sites that we are able to establish. We did not change our approach.

He shortages: Some samples are backlogged due to global He shortages

Training and Professional Development:

To date, project participation has included,

- Four graduate students, Jessica Scholz, Jiahao Wen and Daniela Aguirre at USU, Molly Blakowski
- One graduate student at BYU, Detiare Leifi
- One postdoctoral scientist, Juan Gonzalez-Olalla
- Four technicians, Audree Provard, Mark Devey, Eric Heim, Patrick Strong
- Four Undergraduates, Katie Siesel, Lauren Jones, Margaret Hallerud, Dylan Anderson
- Three external faculty, Bonnie Waring (Imperial, London), Zach Aanderud (BYU), Greg Carling (BYU)

All students are invited to participate in lab meetings (Graduate students and postdocs are required), and with Brahney for one-on one meetings. In group meetings, we have trainings, discuss papers, present and discuss results, and practice talks.

Jessica Scholz MS, was hired to work on dust drivers of nutrient increase in Utahs mountain lakes. Jiahao Wen, an international MS student was hired to work on dust nutrient bioavailability with Brahney. Detiare Leifi was hired to analyse the microbial community composition of dusts with Zach Aanderud (Major Advisor) and Bonnie Waring (External Advisor). Three undergraduate students, Audree Provard, Katie Siesel, Margaret Hallerud, Lauren Jones, and one technician, Eric Heim, were hired with Brahney to assist with project operations. Molly Blakowski is a PhD student working with Brahney who is interested in education and outreach, Molly is assisting with the development of materials for high school students. Dani Aguirre, a PhD student, and Dylan Anderson (undergraduate) are examining watershed controls on the ecosystem effects of dust deposition. Dani will also be evaluating the role of dust on aquatic and terrestrial production. Postdoc Juan Gonzalez is working on dust effects on algal and zooplankton communities using controlled laboratory experiments.

Students have been trained on various aspects of laboratory, analytical, and statistical procedures, as well as field methods. All graduate students are participating in the development of manuscripts. Margaret Hallerud (undergraduate) and Eric Heim (MS level technician) have also participated in the publication of research results to date in the journal *Science*.

Dissemination:

Twenty-four invited and an additional twelve talks on the results of the research to date have been presented. International conferences included the American Geophysical Union, the European Geophysical Union, the Global Microplastic Symposium, Ocean conservancy's Trash Free Seas Alliance, and the Group of Experts on the Scientific Aspects of Marine Environmental Protection meeting in November of 2020. Local and regional presentations took place at the Utah Air Quality Science for Solutions conference in 2020 and 2021, the National Atmospheric Deposition Program's network operations fall meeting, university seminar series, documentary showings and conservation groups. Brahney also presented at the California Assemblies hearing on Environmental Safety in March, 2021.

Brahney has given dozens of interviews for *The Guardian*, *WIRED*, *CNN*, *National Geographic*, amongst other international and national news agencies. Brahney has worked with *Pentagram Designs and Google Arts and Culture* to create an online learning and engagement platform Brahney is working with Matt Simon of *WIRED*, who is writing a book about microplastic research and researchers. Most recently Brahney was interviewed several times for a feature upcoming article in *Popular Science* about increasing dust emissions in the American West. Brahney has given several interviews for broadcast news

including Gerta Van Susteren's 'Voice of America' and 'Full Court Press' and was featured on several podcasts including the *Ocean Protect Podcast*, *Quirks and Quarks (CBC)*, and *Big Picture Science Podcast*. Brahney has appeared in a documentary called 'Overflow', which has been submitted to film festivals. Brahney was also featured in National Geographic, NPR, and Popular Science. Blakowski and Brahney have been featured on KSL TV and Radio

Four papers have been published to date, in the following journals, Science, PNAS, Aeolian Research, Science of the Total Environment, by Brahney lab members as lead authors. An additional six papers have been published by collaborators in Journal of Hazardous Materials, Journal of Geophysical Research - Earth Surface, Water Research, Environmental Science and Technology, and Fundamental Research, and Earth Science Reviews. Brahney has written two lay articles, one for the *Science Breaker* and a second opinion piece published in *The New York Times* (06/26/2020). One chapter has been published in the Encyclopedia of Inland Waters, entitled "Dust and Fog effects on Inland Waters", by Brahney, Reche, and Weathers.

A new chapter for the textbook "Encyclopedia of Limnology", published by Academic Press, Elsevier, has been published. The chapter is titled "Dust and Fog effects on Inland Waters" by Brahney, J., Weathers, K., Reche, I. The chapter outlines our current understanding of dust composition and the capacity for dust to fertilize inland water bodies and influence pH and alkalinity. The state of knowledge on the capacity for dust to influence microbial and algal community composition is provided along with the significant knowledge gaps. The chapter is currently in press.

Curricula for our high-school program is being developed by Brahney and PhD student, Molly Blakowski, and our new extension specialist at USU, Dr. Erin Rivers. Brahney will co-teach a course for high-school educators starting in June 2022 through Portland State University

Products/Other Products:

Databases - Plastic deposition database in ESS-DIVE

Instruments or Equipment - A new dry deposition sampler was tested and deployed at more than 30 locations around the US. The NADP is considering the adoption of this sampler and method

Audio or Video - Videos describing plastic pollution in the atmosphere.

Vox video narrated by Janice Brahney https://twitter.com/voxdotcom/status/1289321212569559040

Video interview

https://www.youtube.com/watch?v=R4MyifvlfbY

Educational Aids or Curricula - Educational website on atmospheric plastic pollution

<https://artsexperiments.withgoogle.com/plasticair/>

Physical Collections - Over 300 dry deposition samples are archived

Models - Model linking back-trajectory models to GIS spatial data

<https://github.com/mhallerud/WindDispersionSources>

Other - Code to calculate wind dispersion sources

<https://github.com/mhallerud/WindDispersionSources>

Audio or Video - Vox Answers: How does plastic from everyday items get swept into the air?

<https://twitter.com/voxdotcom/status/1289321212569559040?lang=en>

Physical Collections - We have >400 samples collected from 15 sites around the American west

Instruments or Equipment - We have produced 30 samplers, 24 are still in operation.

Data and Research Material - We have produced and analyzed data for two publications. 1) on the physical functioning of our sampler for dust collections 2) on dust plastic composition, and 3) over 600 back trajectory models.

Protocols - We have developed protocols surrounding the use and recovery of our dust samples

Physical Collections - We have 120 samples collected from 15 sites around the American west

Plan of Work:

This is the final project report. However, we will continue to analyze the samples as above and expect to produce several additional publications on the composition of dust. Papers will focus on bioavailable nutrient deposition.

Diversity and functions of bacterial symbionts in adelgids (Hemiptera: Sternorrhyncha: Adelgidae)"

Project Director

Carol Von Dohlen

Organization

Utah State University

Accession Number

1012829



Diversity and functions of bacterial symbionts in adelgids (Hemiptera: Sternorrhyncha: Adelgidae)

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Plant-sap-sucking insects are serious pests of agriculture and forests resources. Introduced and invasive species pose the greater threats. With growing concerns over pesticide use and insect resistance, alternative methods for control are needed. Adelgidae are aphidoids that feed solely on conifers. Native adelgid species cause significant economic losses in spruce seed orchards in the U.S. Invasive, introduced adelgids have become serious pests in North America. Hemlock woolly adelgid (HWA) introduced from Japan has nearly eliminated hemlocks in the eastern U.S, dramatically changing the ecology of eastern forests. Balsam woolly adelgid (BWA) introduced from Europe causes significant damage and mortality to true firs across the U.S. and Canada. Tens of millions of tax dollars have been spent to control these pests, without appreciable success. Problems will only intensify as a warming climate promotes more rapid insect reproduction and geographic range expansion.

Most sap-sucking insects harbor bacterial symbionts. Some bacteria are required (obligate) partners that supplement nutrient-poor plant-sap diets, while others are non-required (facultative) symbionts with other, protective roles. Because symbionts are intimate partners essential or beneficial to insect ecology and survival, such microbiota represent a potential alternative to insecticides and predators for control. Microbes have much simpler biology than their hosts, and are more easily manipulated. In addition, any direct effects of microbes on host trees could be negated by focused treatments aimed at toxic substances introduced by microbes, if they can be identified. Before information from microbes could be used to combat pests, however, we must have information about their identities and functions. In contrast to other sap-feeding insects, adelgid symbionts are understudied. Nothing is known about the roles or functions of these symbionts, aside from the preliminary data my laboratory has collected.

The overall goal of this project is to characterize the full diversity of bacterial symbionts that form functional associations with adelgid insects. Based on our preliminary survey and genomic data, we hypothesize that obligate symbionts of adelgids are likely nutritional partners, but may have other roles. We also hypothesize that facultative symbionts in certain adelgids may contribute to their invasive status and to their negative impacts on host plants. In this project, we will survey a broad sample of adelgid species to catalog the diversity and incidence of facultative symbionts, which may have functions in insect-plant interactions, and/or contribute to invasiveness through mediation of environmental stressors or even insecticide resistance. In addition, we will characterize the complete metabolic capabilities of obligate symbionts in two invasive pest adelgids, to determine whether they contribute specific products involved in toxicity to host plants. In these same two adelgids, we will characterize the host-insect products that potentially interact with symbionts regarding metabolic pathways.

Specific objectives are as follows:

1. Identify and inventory obligate and facultative bacterial associates of diverse adelgid species.
2. Finalize genome assembly and annotations of *Pseudomonas*, *Anandiana*, and *Serratia* symbionts of hemlock woolly adelgid.
3. Assemble and annotate complete genomes of *Ecksteinia* and *Steffania* symbionts of balsam woolly adelgid.
4. Sequence, assemble, and annotate transcriptomes of three populations of hemlock woolly adelgid (HWA).

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1. We extracted DNA from 32 species and 61 populations, and amplified and sequenced partial 16S genes from symbionts of approximately 30% of samples and 50% of species. We published a paper describing some initial findings from this work. We also specifically tested for the presence of *Serratia symbiotica* symbionts (originally discovered in hemlock woolly adelgid, *Adelges tsugae* (HWA)) across 20 samples and 11 species. *Serratia* was detected only in *Adelges tsugae* samples. We sequenced, assembled, and annotated the genomes of co-obligate symbionts from four Adelgidae species (two symbionts from each host species): *A. lariciatus*, *A. piceae*, *A. cooleyi*, and *Pineus similis*. We completed a manuscript describing and comparing the metabolic capabilities of these obligate symbionts along with those of HWA.

Objective 2. We sequenced and annotated complete genomes of *Annandia adelgestsuga* and *Pseudomonas adelgestsugas* symbionts of HWA sampled from *Tsuga canadensis* from Massachusetts. Sequencing coverage of the *Serratia symbiotica* symbiont from this sample was insufficient to obtain a good assembly. In an effort to assemble *Serratia*, we obtained Illumina NGS sequence data from the HWA population from *Tsuga sieboldii* in Japan, which also contains the *Serratia symbiotica* symbiont, and from which the North American population was derived. The genome was difficult to assemble due to many repetitive regions, and this work is ongoing. We completed a manuscript describing the *Annandia adelgestsuga* and *Pseudomonas adelgestsugas* symbiont genomes, describing the metabolic capabilities and the putative nutritional contributions and cooperative functions of these symbionts. We also compared their genomes to those of other nutritional symbionts in sap-feeding insects. We obtained Illumina genomic data for samples of HWA from three additional strains: one from *Tsuga diversifolia* in Japan, one from *T. heterophylla* from northwestern US, and one from *T. chinensis* in China. These samples provide comparative data for symbionts from the *T. sieboldii* and eastern US samples. We performed initial assemblies of the data, which have yielded good coverage and long contigs from the Japan *T. diversifolia* and China strains. Illumina NGS data from the western North America strain of HWA on *Tsuga heterophylla* from a first sample yielded no data for symbionts. We obtained a new sample of this strain and sequenced it. Results were delayed due to the Covid-19 pandemic. Initial analyses of the data show that the assembly of the *Pseudomonas* symbiont is fragmented and needs more work.

Objective 3. We sequenced, assembled, and annotated complete genomes of *Ecksteinia* and *Steffania* obligate symbionts of balsam woolly adelgid (BWA) from Farmington Canyon, UT. The *Steffania* genome was found to have metabolic capabilities similar to junior symbionts of other *Adelges* spp. The *Ecksteinia* genome assembly, however, was challenging and did not assemble in one piece. To improve our results, we sequenced a second sample from Mantua, UT. The data were high quality and coverage of both symbionts was sufficient to assemble, close, and annotate both genomes. These and all other symbiont genomes were submitted to GenBank.

Objective 4. The focal species of this objective was changed to *Adelges cooleyi*. In 2019 we successfully dissected bacteriomes from 4th-instar insects of the spruce gall generation, and obtained high-quality RNA from both bacteriome and whole-body samples. Our first attempts to obtain RNA from Douglas-fir generations in 2021 were unsuccessful due to degradation of RNA in the dissection buffer. We experimented with different buffers, found one with good preservation qualities, and in 2022 successfully obtained RNA from Douglas-fir samples (both bacteriome and whole-body). Good-quality RNA was successfully extracted from these samples. In 2022 we repeated dissections from spruce gall generations to get data from 3rd-instar insects for comparison. We also conducted microscopy studies of bacteriomes on insect from both host plants. Transmission electron microscopy and light microscopy show that there are two cell types in the bacteriome. Initial results suggest the gall generations have more, smaller, empty bacteriocytes, and those with bacteria present are mainly filled with *Vallotia*, the more abundant symbiont. Needle-feeding generations on Douglas-fir have more bacteriocytes filled with symbionts and the abundance of *Profftia* symbionts is increased.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Training and Professional Development:

This project provided training in general molecular biology laboratory skills, computer analysis, and bioinformatic for three PhD students and four undergraduate students, and helped to support the dissertation research of one PhD student. Specific skills gained by graduate students included purifying high quality genomic DNA and RNA, bioinformatic assembly of whole bacterial genomes from Illumina next-generation sequencing, and annotation and analysis of genomes. Specific training for undergraduates included learning how to purify whole-genomic DNA from insects, perform PCR gene amplification, purify PCR products, compile/correct contigs and align sequences, design primers for PCR, and use GenBank and other bioinformatics resources.

Dissemination of results were through publications in peer-reviewed journals, presentations at the Annual Meeting of the Entomological Society of America, and a PhD dissertation. Complete genomes of dual symbionts from five adelgid species were submitted to the public database, GenBank. This project also provided opportunities for six Native American students from the USU Blanding campus to learn about insect-bacterial symbioses and participate in field and bench research in the PI's laboratory.

Publications

Dederich, A., Halbert, S., & von Dohlen, C. D. (2022). Description of a new species of Hamamelistes forming galls on Fothergilla spp. (Hamamelidaceae) and the generic limits of Hormaphidini (Sternorrhyncha: Aphididae: Hormaphidinae). *To appear in Zootaxa*.

Dial, D. T., Weglarz, K. M., Aremu, A. O., Havill, N. P., Pearson, T. A., Burke, G. R., & von Dohlen, C. D. (2021, January 01). Transitional genomes and nutritional role reversals identified for dual symbionts of adelgids (Aphidoidea: Adelgidae). *ISME Journal*, epub 20210910.

Mech, A. M., Harper, S. J., Havill, N. P., von Dohlen, C. D., & Burke, G. R. (2017, December). Ecological factors influencing the beneficial endosymbionts of the Hemlock Woolly Adelgid (Hemiptera: Adelgidae). *Insect Science*.

Nieto Nafria, J. M., von Dohlen, C. D., Moreno-Gonzalez, V., Ortego, J., & Mier Durante, M. P. (2019). The species of Uroleucon (Hemiptera: Aphididae) living on Adesmia (Fabaceae) in Argentina, with the description of a new species. *Zootaxa*, 4555(4), 561–572.

Nieto Nafria, J. M., von Dohlen, C. D., Brown, P., Mier Durante, M. P., Ortego, J., López Ciruelos, S. I., & Licht, M. (2019, April). Three new species of the genus Neuquenaphis (Hemiptera, Aphididae, Spicaphidinae) from southernmost South America. *Zootaxa*, 4555(5), 525–545.

Ortego, J., Licht, M., Mier Durante, M. Pilar, & Nieto Nafria, J. (2022). Blanchardaphis poikila syn. n. to B. capitophoroides and Blanchardaphis syn. n. to Lambersius (Hemiptera, Aphididae, Aphidinae, Macrosiphini, Uroleucon). *To appear in Zootaxa*.

Weglarz, K. M., Havill, N. P., Burke, G. R., & von Dohlen, C. D. (2018, June 01). Partnering with a pest: Genomes of hemlock woolly adelgid symbionts reveal atypical nutritional provisioning patterns in dual-obligate bacteria. *Genome Biology and Evolution*, 10(6), 1607-1621.

von Dohlen, C. D., Spaulding, U., Patch, K., Weglarz, K. M., Footitt, R. G., Havill, N. P., & Burke, G. R. (2017, June). Dynamic acquisition and loss of dual-obligate symbionts in the plant-sap-feeding Adelgidae (Hemiptera: Sternorrhyncha: Aphidoidea). *Frontiers in Microbiology*, 8, 1-15.

Presentations

Brunet, B. (Presenter & Author), Burke, G. (Author Only), Footitt, R. (Author Only), Havill, N. (Author Only), Johnston, S. (Author Only), von Dohlen, C. D. (Author Only), ICE 2022, "Building a Phylogeny for the Adelgidae using Shotgun Phylogenomics," International Congress of Entomology, Helsinki, Finland. (July 19, 2022 - July 24, 2022)

Licht, M. (Presenter & Author), von Dohlen, C. D. (Author Only), ICE 2022, "PACH-ed with Species: Parsing a Cryptic Species Complex (Pachypsylla: Psylloidea:Hemiptera)," International Congress of Entomology, Helsinki, Finland. (July 19, 2022 - July 24, 2022)

Dederich, A. (Presenter & Author), von Dohlen, C. D. (Author Only), Annual Meeting of the Entomological Society of America, "Consequences of host life cycles for symbiont genome evolution," Entomological Society of America, Denver, CO. (November 2021)

Dial, D. (Presenter & Author), Weglarz, K. (Author Only), von Dohlen, C. D. (Author Only), Havill, N. (Author Only), Burke, G. (Author Only), Joint Eastern & Southeastern Branch Meeting of the Entomological Society of America, "Differential division of labor in the ancient symbionts of sap-sucking insects (Sternorrhyncha: Adelgidae)," Entomological Society of America, Mobile, AL. (March 2020)

Dial, D. (Presenter & Author), Burke, G. (Author Only), von Dohlen, C. D. (Author Only), Weglarz, K. (Author Only), Havill, N. (Author Only), Annual Meeting of the Entomological Society of America, "Differential division of labor in the ancient symbionts of sap-sucking insects (Sternorrhyncha: Adelgidae)," Entomological Society of America, St Louis, MO. (November 2019)

Dial, D. T. (Presenter & Author), Burke, G. R. (Author Only), Weglarz, K. M. (Author Only), Havill, N. P. (Author Only), von Dohlen, C. D. (Author Only), Gordon Research Seminar: Symbiotic Tipping Points: Evolutionary Forces Driving Symbiotic Interactions, "Differential division of labor in the ancient symbionts of sap-sucking insects (Sternorrhyncha: Adelgidae)," Gordon Research Seminar, Mount Snow, Vermont. (June 2019)

Dial, D. (Presenter & Author), Burke, G. (Author Only), Weglarz, K. (Author Only), Havill, N. (Author Only), von Dohlen, C. D. (Author Only), Southeastern Branch Meeting of the Entomological Society of America, "Differential division of labor in the ancient symbionts of sap-sucking insects (Sternorrhyncha: Adelgidae)," Entomological Society of America, Mobile, AL. (March 2019)

Licht, M. (Presenter & Author), Nieto Nafria, J. (Author Only), Jaime, O. (Author Only), von Dohlen, C. D. (Author Only), Annual Meeting of the Entomological Society of America, "Going Native: Aphid Colonization of South America," Entomological Society of America, Vancouver, BC, Canada. (November 2018)

Burke, G. (Invited Lecture), Weglarz, K. (Author Only), Havill, N. (Author Only), von Dohlen, C. D. (Invited Lecture), Annual Meeting of the Entomological Society of America, "Chefs and sous-chefs in the adelgid kitchen: Differential division of labor in the ancient symbionts of sap-sucking insects (Sternorrhyncha: Adelgidae)," Entomological Society of America, Denver, CO. (November 2017)

Burke, G. (Invited Lecture), Weglarz, K. (Author Only), Havill, N. (Author Only), von Dohlen, C. D. (Invited Lecture), Annual Meeting of the Entomological Society of America, "Passing the torch: an obligate adelgid symbiont steps back from its role as the primary producer," Entomological Society of America, Denver, CO. (November 2017)

Weglarz, K. (Presenter & Author), Burke, G. (Author Only), Havill, N. (Author Only), von Dohlen, C. D. (Author Only), Annual Meeting of the Entomological Society of America, "Vacillating Vallotia: does a switch in metabolic role influence the course of symbiont genome decay in adelgids (Hemiptera: Sternorrhyncha: Adelgidae)?," Entomological Society of America, Denver, CO. (November 2017)

Data and Research Material - Purified RNA from dissected bacteriomes and whole-body remainders from spruce gall and Douglas-fir generations of *Adelges cooleyi*.

Data and Research Material - Purified RNA from gall generations of *Adelges cooleyi*.

Data and Research Material - Dissected bacteriomes from gall generations of *Adelges cooleyi*.

Data and Research Material - Insect samples in ethanol of *Adelges tsugae* from Bhutan.

Data and Research Material - Partial genomes assemblies for two endosymbionts of one strain of Hemlock Woolly Adelgid (*Adelges tsugae*) from Tsuga heterophylla from Washington state.

Data and Research Material - Purified genomic DNA for Hemlock Woolly Adelgid (*Adelges tsugae*) from Tsuga heterophylla from Washington state.

Data and Research Material - Purified genomic DNA for 8 species of adelgids (Hemiptera: Adelgidae)

Data and Research Material - Complete, annotated genomes for dual symbionts of three strains of hemlock woolly adelgid (*Adelges tsugae*) and four other *Adelges* species.

Data and Research Material - Complete, annotated genomes for dual symbionts of *Pineus similis*, *Adelges cooleyi*, *Adelges lariciatus*, and *Adelges piceae* (Hemiptera: Sternorrhyncha: Adelgidae).

Data and Research Material - Specific PCR data on presence/absence of *Serratia* symbionts across diverse species of adelgids.

Data and Research Material - 16S sequences of *Serratia* symbionts from specific PCR products generated from adelgid species.

Data and Research Material - Complete, annotated genomes for Annandia and Pseudomonas symbionts of hemlock woolly adelgid (*Adelges tsugae*) from eastern North America.

Data and Research Material - Genomic data for Annandia, Pseudomonas, and Serratia symbiotica symbionts of hemlock woolly adelgid (*Adelges tsugae*) from *Tsuga sieboldii* from Japan.

Data and Research Material - 16S sequence data for symbionts and other microbial associates of ~20 populations/species of adelgids.

Identifying biotic and abiotic controls of plant regeneration to advance sagebrush steppe conservation and restoration

Project Director

P Adler

Organization

Utah State University

Accession Number

1012844



Identifying biotic and abiotic controls of plant regeneration to advance sagebrush steppe conservation and restoration

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

1. Determine how plant-soil feedbacks influence the establishment of native perennials in the sagebrush steppe
2. Determine how climate change will alter impacts of the cheatgrass invasion

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: How do plant-soil feedbacks influence the establishment of native perennials in the sagebrush steppe?

This work was carried out in conjunction with an NSF award that funded post-doc Anny Chung to conduct a two-year field experiment.

We found that plant establishment is limited more by soil microbes than by root competition. However, evidence for species-species plant-soil feedbacks or even species-specific competitive effects was extremely weak. This result is surprising in light of our analyses of long-term observational data which show that intraspecific competition limits recruitment much more than does interspecific competition. The implication is that field experiments and observational studies can return quite different estimates of species interactions, a conclusion consistent with a recent removal experiment we conducted, and with studies by other ecologists as well. Comparison of the field and greenhouse soil-feedback experiments shows similar inconsistency, with evidence of positive microbial effects emerging in the greenhouse. Our discipline clearly has challenges to tackle in improving our methods for estimating the effects of species interactions. I am interested in developing new methods based on integration of experiments, observations, and advanced statistical methods. These results are reported in a manuscript now in the second round of review at Ecology.

Post-doc Chung also led a perspective piece arguing that more mechanistic approaches are needed to advance research on plant-soil feedbacks. The manuscript recently came back from Trends in Ecology and Evolution with a decision of "Revise."

Objective 2: How will climate change alter impacts of the cheatgrass invasion?

This work was carried out in coordination with our NSF "Bromecast" award.

Successful completion of pilot common garden experiment

In spring 2021, we completed our pilot common garden experiments at the Cheyenne, WY, Dubois, ID and Boise, ID sites. Our

primary goal was to test our colored gravel “albedo” treatment for manipulating soil temperature. The results of our pilot study have given us confidence to proceed with the colored gravel alternative. At all three sites, black gravel increased soil temperatures at least 2 degrees C above the white gravel treatment. The difference in temperature also translated into differences in plant phenology and growth, with more rapid phenology and increased growth on black gravel. Finally, we learned valuable lessons about how to apply the gravel, glue seeds to toothpicks and plant them, and monitor plant responses. These lessons helped us implement the full-scale common garden experiments this summer and fall.

Implementation of full common garden experiments

We began implementing a larger-scale common garden experiment in the spring of 2021 across four sites in the Intermountain West (two sites near Boise, ID; one in Dubois, ID; one in Cheyenne, WY). We established denuded plots using a 2 x 2 factorial design of cheatgrass density (low vs high) and plot temperature (white vs black gravel). Every site contains 40 plots (10 replicates of each density x temperature treatment in a randomized block design) each planted with 100 cheatgrass seeds from 95 different genotypes for a total of 16,000 planted seeds across all sites. Before planting, we glued all cheatgrass seeds to toothpicks and labeled toothpicks of different genotypes with unique color combinations to more effectively track individual seeds in randomized planted grids and monitor source population demography and growth. We planted 10 toothpicks of 18 genotypes (180 seeds total) in additional grid rows to destructively sample plants and measure morphological and physiological traits in high elevation white plots and low elevation black plots (to produce the greatest variability in traits).

In addition to seed planting, we covered plots with black or white gravel to change surface albedo and monitor the effect of simulated warming on cheatgrass demography and growth. We have also installed soil temperature and moisture sensors to monitor environmental conditions across sites and treatments.

We recently completed the harvest of the 2021 cohort, and are now preparing to plant the 2022 cohort.

Implementation of satellite site experiments

We have recruited volunteers to conduct the distributed, satellite experiments across western North America from British Columbia, Canada to Arizona. This year, we have about 40 sites planned, involving about 40 BromeCast participants (some sites have multiple volunteers). Approximately 25 of these sites have confirmed their fall 2021 planting. A total of 150 cheatgrass seeds are planted on toothpicks in every site in either control or vegetation removal treatments to measure the effects of interspecific interactions on cheatgrass demography. We will also monitor plant species composition and ground cover and soil-surface characteristics during spring surveys to extend the inference of environmental covariates on cheatgrass demography beyond the common garden sites, and to test model predictions.

Genomic analyses (led by collaborators at Penn State University)

In 2019 and 2020, we recruited volunteers to collect seeds from more than 250 populations located mostly western North America, but we also acquired seeds from populations worldwide. In Fall 2020, we extracted DNA from six representative genotypes that were sent for sequencing at 50X coverage to the DOE Joint Genome Institute and used for making preliminary genome assemblies. In Fall 2020-Spring 2021 we bulked over 200 cheatgrass genotypes from the native (54) and invaded (149) range in a growth chamber with controlled conditions. Extracted DNA was sent to the Texas A&M sequencing facility to be sequenced at ~4.4X coverage. Additional plants were grown for phenotyping. These data will allow us to dissect the genetic basis of variation in life history strategies, and how strategies differ or not between the native and invaded range.

Publications

Pls Lasky, Hooten & Adler published a review and perspective manuscript in *Proceedings of the Royal Society B* titled, What processes must we understand to forecast regional scale population dynamics? The focus of the manuscript is the urgent challenge being addressed by this NSF grant: predicting the regional scale population dynamics of species facing environmental change. Biologists suggest that we must move beyond predictions based on phenomenological models and instead base predictions on underlying processes. For example, population biologists, evolutionary biologists, community ecologists, and ecophysiologicalists all argue that the respective processes they study are essential. Our manuscript asks whether our models include processes from all of these fields? We argue that answering this critical question is ultimately an empirical exercise requiring a substantial amount of data. To motivate and facilitate the necessary data collection and integration, we first review the potential importance of each mechanism for skillful prediction. We then develop a conceptual framework based on reaction norms, and propose a hierarchical Bayesian statistical framework to integrate processes affecting reaction norms at different scales.

Adler published a paper in *Ecography* in 2020 titled, "Matching the forecast horizon with the relevant spatial and temporal processes and data sources," that develops approaches for studying slow ecological processes that may lag behind the pace of climate change.

Post-doc Toby Maxwell led a paper describing our method for manipulating surface albedo, based on our pilot experiment. It is now in the second round of review at *Plant and Soil*.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report

Training and Professional Development:

Post-doc Anny Chung was mentored by PI Adler. She began an Assistant Professor position at the University of Georgia in August, 2019.

Chung and Adler trained two undergraduates field technicians in summer 2018 and again in summer 2019. The students were trained in plant species identification, plant species composition monitoring, sampling and processing of biomass samples and soil samples, data entry, spatial data digitization, and some simple computer programming.

The combination of this UAES project and Adler's NSF-funded Bromecast project has provided training opportunities for 11 hourly research assistants. They helped process seed collections, conduct the seed bulking at UN Reno, and implement common garden experiments and satellite experiments. The project has also provided partial support for two post-docs working with Bromecast Co-PI Germino in Boise, who helped design and implement the pilot common garden experiments.

Dissemination:

Under Objective #1, Chung presented results of the plant-soil feedback experiment at the 2019 annual meeting of the Ecological Society of America.

Under Objective #2, cheatgrass, PI Adler presented the work on the hierarchical modeling framework in a poster at the ESA 2020 annual meeting, as part of the Leading Ecologists spotlight.

The project also involves a public outreach component lead by the Denver Botanic Garden. They are working with Idaho Botanical Garden (in Boise) and Red Butte Botanic Garden (in Salt Lake). They fabricated fiberglass hexagon chambers and shipped them to the two other sites. Due to shut downs from COVID, they were quite delayed in getting the chambers set up, but were able to get all the chambers set up at all 3 sites (the above 2 plus Denver Botanic Gardens) this year and begin data collection. They have 5 plots (paired with a control plot) set up at each site. They decided to focus on phenology for data collection since all sites have public programs linked to NPN so it is easy for everyone (staff, volunteers, visitors) to collect data on the NPN app (Nature's Notebook). They used this year primarily to figure out how things would work at each site and troubleshoot site-specific issues (high winds requiring larger ground staples to hold some in place; unintended mowing of a control plot) and plan to initiate more rigorous public outreach and data collection starting in the spring. Each site will focus on incorporating the chambers into their existing programs which vary by site but include school programs such as field trips and camps and docent-led tours. The interpretation and engagement staff at Denver Botanic Gardens are planning the

interpretation development around plants and climate change. Each of the other sites completed an interpretation survey for the Denver staff so they could better understand the needs and capacity at each site so that materials developed will be useful and usable.

Publications

Refereed Journal Articles:

Adler, P., White, E., & Cortez, M. (2020). Matching the forecast horizon with the relevant spatial and temporal processes and data sources. *Ecography*, 43(11), 1729--1739.

Adler, P., Kleinhesselink, A. R., Hooker, G., Taylor, J. B., Teller, B., & Ellner, S. (2018). Weak interspecific interactions in a sagebrush steppe: evidence from observations, models, and experiments. *Ecology*, 99, 1621-1632. 1073,

Anderson, T. M., al, e., & Adler, P. (2018). Herbivory and eutrophication mediate grassland plant nutrient responses across a global climatic gradient. *Ecology*, 99, 822-831.

Chung, Y. A., Ke, P.-J., & Adler, P. Mechanistic approaches to investigate microbe-mediated plant competition. *Trends in Ecology and Evolution*.

Chung, Y. A., Monaco, T., Taylor, J. B., & Adler, P. Do plant-soil feedbacks maintain coexistence in a sagebrush steppe?

Hautier, Y., al, e., & Adler, P. (2018). Local loss and spatial homogenization of plant diversity reduce ecosystem multifunctionality. *Nature Ecology and Evolution*, 2, 50-56.

Hodapp, D., al, e., & Adler, P. (2018). Spatial heterogeneity in species composition constrains plant community responses to herbivory and fertilisation. *Ecology Letters*, 21, 1364-1371.

Kleinhesselink, A. R., & Adler, P. (2018). The response of big sagebrush (*Artemisia tridentata*) to interannual climate variation changes across its range. *Ecology*, 99, 1139-1149.

Kulmatiski, A., Adler, P., & Foley, K. M. (2020). Hydrologic niches explain species coexistence and abundance in a shrub-steppe system. *Journal of Ecology*, 108(3), 998--1008.

Lasky, J. R., Hooten, M. B., & Adler, P. (2020, December). What processes must we understand to forecast regional-scale population dynamics? *Proceedings of the Royal Society B: Biological Sciences*, 287(1940), 20202219.

Laughlin, D., Strahan, R., Adler, P., & Moore, M. (2018). Survival rates indicate that correlations between community-weighted mean traits and environments are unreliable estimates of the adaptive value of traits. *Ecology Letters*, 21, 411-421.

Maxwell, T. M., Germino, M., Romero, S., Porensky, M., Blumenthal, D. M., Brown, C., & Adler, P. Experimental manipulation of soil-surface albedo alters phenology and growth of *Bromus tectorum* (cheatgrass). *Plant and Soil*.

Renwick, K., Curtis, C., Kleinhesselink, A. R., Schlaepfer, D., Bradley, B., Aldridge, C., Poulter, B., & Adler, P. (2018). Multi-model comparison highlights consistency in predicted effect of warming on a semi-arid shrub. *Global Change Biology*, 24, 424-438.

Tredennick, A., Kleinhesselink, A. R., Taylor, J. B., & Adler, P. (2018). Ecosystem functional response across precipitation extremes in a sagebrush steppe. *PeerJ*, 6, e4485.

Tredennick, A., Adler, P., Hooker, G., & Ellner, S. (2018). Size-by-environment interactions: a neglected dimension of species' responses to environmental variation. *Ecology Letters*, 21, 1757-1770.

Presentations:

Terry, T. J., Adler, P., Ecological Society of America Annual Meeting, "Climate drives dryland plant response to disturbance: A lesson from natural gas pipeline corridors." (2021 - Present)

Adler, P., Western Drought Resilience Workshop, "Ranching, rangelands, and resilience: ensuring adaptive capacity in an increasingly variable climate," USDA Southwest Climate Science Hub. (2020 - Present)

Chung, A. (Author Only), Monaco, T. (Author Only), Taylor, J. B. (Author Only), Adler, P., Ecological Society of America Annual Meeting, "From phenomenon to mechanism: Are plant-soil feedbacks maintaining coexistence in the sagebrush steppe?," Ecological Society of America, Salt Lake City. (2020)

Adler, P., Lasky, J. (Author Only), Hooten, M. (Author Only), Ecological Society of America Annual Meeting, "What processes must we understand to forecast the impact of global change on species distribution and abundance?," Ecological Society of America, Salt Lake City, UT. (2020)

Other Products

Other - We have created a project website (<https://bromecast.wixsite.com/home>) to recruit participants to the Bromecast network, share protocols and data with them, and share our research with the broader research community.

Plan of Work:

Not applicable, this is the **FINAL** report for this project.

Sustainable Natural Resources Education

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7001909



Forecasting and Adapting to Drought

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The western United States is experiencing an unprecedented megadrought that has persisted for the entirety of the 21st century (Williams et al., 2022). A megadrought is described as a severe drought lasting more than 10 years (Steiger et al., 2021). Western states have been persistently warm and dry for the last two decades; 2000 to 2021 was the driest period in history which was punctuated by the driest and third warmest year ever recorded between 2020 and 2021 (Mankin et al., 2021; Williams et al., 2022). The nexus between extreme water scarcity and mounting pressures on water supplies in Utah highlights the urgent need to connect Utahns to emerging research and management perspectives on drought outlooks, planning, and conservation.

In the last 10 years, Utah State University (USU) has published more than 1,000 documents related to drought, including climate modeling and drought prediction, the ecological impacts of drought on natural resources and wildlife, and the social dimensions of drought. Connecting the public with this information is critical as the state faces complex challenges in managing water supplies and mitigating the irreversible damage to Utah's natural resources during severe drought conditions. In response, USU Extension provided a forum to connect stakeholders and the public with important information about drought at the *Spring Runoff Conference*. Led by E. Rivers and team, the Spring Runoff Conference convened university experts, federal and state agencies, natural resource managers, and community members to share cutting-edge research on drought forecasting and conservation practices and community strategies for adapting to drought through water efficient practices.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

USU Extension organized the 2022 Spring Runoff Conference to connect stakeholders and the public to research and information about the severity of the current megadrought in Utah. The goal of the 2022 Spring Runoff Conference was to improve public knowledge about the impacts of the megadrought in Utah and promote behavior change to improve water efficiency. The conference facilitated a method of distributing information and educational resources about drought and conservation strategies to federal and state agency professionals, natural resource managers, Extension County Faculty, and members of the public.

A total of 135 participants attended, including 11 USU Extension County Faculty and Specialists, 24 agency professionals from the Utah Department of Environmental Quality (Division of Water Quality, Division of Drinking Water), the Utah Department of Natural Resources (Division of Water Resources; Division of Wildlife Resources; Division of Forestry, Fire, and State Lands; Utah Geological Survey), and the Utah Department of Agriculture and Food. Also, in attendance were seven (7) members of non-profits and local water districts; and 93 university faculty and staff. Participants were predominantly from the Wasatch Front

(29%) and Logan (67%), but conference attendance represented all regions of Utah (see Figure 1). Participants identified predominantly female (60%) and white (80%), with 30% identifying as male, 7.5% identifying as Hispanic or Latinx, 5% identifying as American Indian or Alaskan, and 2.5% identifying as Asian.

Briefly describe how your target audience benefited from your project's activities.

The 2022 Spring Runoff Conference convened a diverse group of stakeholders. During five (5) hours of educational activities facilitated by USU Extension, there were also 12 presentations from two (2) federal agencies, and four (4) state agencies. A post-event survey was conducted to evaluate short-term outcomes of the conference. Survey results ($n = 45$) described changes in participants' knowledge and intentions to adopt water conservation practices after conference attendance. A majority of participants (74%) reported knowledge gain in one or more topics about drought as a result of attending the conference. Notably, about 40% of participants indicated they gained knowledge about federal, state, and local drought response and perspectives, 49% indicated they gained knowledge about the impacts of drought in the Colorado River, and 47% indicated they gained knowledge about innovations in forecasting drought. While some participants indicated they were already an expert in the topics presented at the conference, the majority of participants left the conference with knowledge about critical issues surrounding the drought in Utah. As a result of the conference, about 36% of participants reported they intend to use water optimization practices, 55% reported they intend to consider the collection and use of graywater, and 70% reported they intend to encourage community response to drought through everyday practices. Many participants indicated they were already participating in these practices. For example, about 57% of participants indicated they are already utilizing water optimization practices.

Briefly describe how the broader public benefited from your project's activities.

Providing education through a conference format is an effective strategy for USU Extension to engage stakeholders and clientele. There is an urgent need to address water issues and management strategies in Utah (Narine, 2019), and it is critical for USU Extension to continue providing up-to-date resources to help communities respond to emerging challenges in water management and conservation. USU Extension plans to continue planning and implementing the Spring Runoff Conference annually to provide a forum for agency professionals, Extension faculty, and the public to connect and share resources for managing water quality and improving water efficiency. Creating and sustaining synergy between community needs, state agency management priorities, and USU research is essential to foster a coordinated response to the growing water challenges in the state for a sustainable water future.



USU Water Quality Extension Education

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Visitation to Utah's public lands has increased over the past decade (Smith & Miller, 2020), while during the COVID-19 pandemic, that trend not only continued but surged nationwide (Outdoor Foundation, 2021). While outdoor recreation is beneficial to individuals' physical and mental health and the economy, it has led to an increase in garbage ending up on trails, parks, neighborhoods, and our waterways. National parks have documented more graffiti and litter during the coronavirus pandemic (Capron, 2020). In response, agencies have taken to their social media accounts asking followers for any information on transgressors. In Utah, the Division of Wildlife Resources requested public support on social media to help fight littering and encouraged reporting of license plate numbers and vehicle descriptions to track down offenders. Litter pollution is more than an aesthetic problem. Trash poses both physical threats (e.g., entanglement and gastrointestinal blockage for wildlife) and chemical threats (e.g., breakdown of toxic chemicals and bioaccumulation of chemicals in wildlife). When plastics break down, they can accumulate in rivers, lakes, oceans, and even in the atmosphere.

Brahney et al. (2020) estimate that in the western United States, over 1,000 tons of microplastics (or more than 123 million plastic water bottles) are deposited annually into protected lands. The problem of litter pollution is evident. Educating the public on litter pollution and its effects on natural ecosystems, human health, and public lands is only part of the solution. Led by H. Braithwaite, USU Extension found ways to involve the public in hands-on remediation of litter pollution is an important step to creating long-term solutions and stewardship of our public lands.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Pack It Out Utah was created to combat the increase in garbage due to a surge in visitation to recreational public lands. The cleanup was a week-long event encouraging people across the state of Utah to take initiative and be good stewards of our watersheds and public lands by collecting trash that would otherwise negatively impact our landscapes, waterways, wildlife, and public health. Utah State University Water Quality Extension (USU WQE) created a webpage with information on the need for a statewide cleanup, a map with recommended clean-up and trash drop-off locations, registration, online and printable datasheets to record trash collection, safety considerations, and ways to get involved on social media. Clean-up sites were chosen in collaboration with state agencies, locally based partners, nonprofit organizations, and public suggestions. Pack It Out Utah's primary audience is the general public living within the state of Utah. This includes people of all ages who would like to volunteer their time to remove trash from public lands, waterways, and their communities. Participants of the cleanup were diverse, including concerned individuals, families, nonprofits, organizations and businesses, and entire neighborhoods.

Briefly describe how your target audience benefited from your project's activities.

During its pilot year in 2020, Pack It Out Utah registered 352 individuals who contributed to the removal of more than 870 pounds of trash in seven (7) out of ten (10) major watersheds in Utah. Between 2021 to 2022, USU WQE and partner organizations were able to host local clean-up events for volunteers. People could also register and participate on their own or in small independent groups. There were 12 local clean-up events which played a significant role in the increase of participation and garbage cleaned up. Pack It Out Utah registered over 570 participants who removed more than 10,730 pounds of trash in seven (7) out of ten (10) major watersheds in Utah. To date, Pack It Out Utah volunteers have removed more than 11,000 pounds of trash from Utah's public lands and waterways. Volunteer hours were valued at \$42,924 with 1,504 hours based a volunteer hourly rate of \$28.54 (Independent Sector, 2021).

Briefly describe how the broader public benefited from your project's activities.

The Pack It Out Utah cleanup has been well-received by state, local, and nonprofit partners. The increase in participation since its inception in 2020 indicates residents' perceptions toward the benefit of the event as they continue to volunteer their time and energy on the cleanup. Pack It Out Utah partners indicated that USU WQE resources and assistance were well-prepared and helpful. All partners indicated they would recommend to their friends and colleagues to form a partnership with USU WQE. Feedback on what worked well consistently indicated that the marketing and social media resources were well-prepared and easy to use and share on partner platforms. Feedback also consistently commended the option for participants to join the cleanup in multiple ways, including choosing sites from the location map or participating in a local event, as well as the efforts made to host events across the state. Suggestions for improvement included creating information toolkits for city councils and governments to organize and raise awareness for cleanups in their cities, as well as planning more localized events in the future.

The largest challenge is trash disposal at different locations. Due to the statewide nature of Pack It Out Utah, organizing appropriate disposal methods for different individuals and events is a complicated task. The Pack It Out Utah team aims to overcome this challenge by forming relevant partnerships and acquiring additional funding to provide dumpsters during events. Another area for improvement is communication and coordination with federal land agencies to collaborate on approved sites for clean-up efforts since some site locations require agency approval. An increased effort to inform local and state news outlets to spread awareness of the event will be prioritized in upcoming years. Additionally, USU WQE plans to expand Pack It Out Utah's reach to include more southern and central Utah partners and locations and to increase the number of in-person cleanup events.

Critical Issue

Community Resilience

[Exploring the Relationship Between Natural Resource Dependency and Suicide in Rural Utah](#)

Project Director

Jessica Schad

Organization

Utah State University

Accession Number

1022945



Exploring the Relationship Between Natural Resource Dependency and Suicide in Rural Utah

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective 1: Analyze Suicide Rates and Trends in Rural Utah (Years 1-4)

Objective 2: Examine Individual and Community-Level Factors in Suicide Deaths (Years 1-5)

Objective 3: Examine Barriers to Suicide Prevention (Years 1-5)

Objective 4: Work with Rural Communities to Develop Suicide Prevention Strategies (Years 1-5)

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishment:

Major activities completed:

With funding from a UAES seed grant ("Building Community Resilience to Address Mental Health and Suicide in Rural Natural Resource Dependent Places in Utah") we have focused this year on preparing for (including seeking and obtaining IRB approval) and collecting data with a) USU Extension Agents doing work related to mental health (10 completed and transcribed) and b) conducting two case studies in rural natural resource dependent places (still in field but nearly 50 interviews with residents and leaders conducted). We have also analyzed secondary survey data from the Utah Wellbeing Project that is at the intersection of mental health and wellbeing in rural Utah communities.

The graduate research assistant on this project has developed her dissertation proposal in relation to it, defended it to her dissertation committee, and is now working on finishing up data collection and starting on data analysis.

Specific objectives met:

This year our work focused on gathering data and starting to analyze it with reference to the following objectives: Objective 2- What types of community and individual-level factors play a role in mental health/suicide trends in NR dependent places? How do NR transitions and/or type of NR dependency in a community influence mental health and rural suicide patterns? What community-level factors mediate the impact of shifts on mental health issues/suicide rates?; Objective 3-What role does mental health access and/or mental health stigma play in preventing people from getting the help they need in NR dependent places?; and Objective 4-What do residents and leaders of NR dependent places see as needed solutions or resources for addressing mental health issues/suicide?

Significant results achieved, including major findings, developments, or conclusions (both positive and negative):

We have made good progress on our case studies, including developing connections with local organizations working on mental health issues and USU Extension. In our initial analysis of the Utah Wellbeing survey data we have also found that residents' perspectives on mental health and wellbeing at the city/town level across the rural-urban continuum vary, with rural places experiencing poorer mental health and wellbeing outcomes generally, but with variation between rural place types.

Key impacts or other accomplishments realized:

2025-2027 Chair Elect, *Rural Population Research Network/W-5001 Rural Population Change and Adaptation in the Context of Health, Economic, and Environmental Shocks and Stressors* (elected position)

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Policymakers and practitioners working in rural parts of Utah and elsewhere.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

We have shifted our focus more exclusively on mental health in rural natural resource dependent areas, but are still examining how mental health relates to suicide.

As with last year, the PhD student working on this project has been dealing with some personal and family health issues (father had extended stay in hospital with COVID-19 and passed away), and so we are delayed a bit on some objectives (objective 1 in particular), but are still making good progress. We had initially planned to start field work during fall of 2021, but delayed it for health- and pandemic-related reasons. We started the field work in case study communities in fall of 2022. We also are focusing only on two communities in order to gather more data in those places than if we spread it out over four.

Training and Professional Development:

I have been working closely with a PhD student and research assistant who is working on this project for her dissertation. We meet (virtually) nearly weekly to discuss progress and goals. Over the course of the last year, I have also been able to attend (both online and in-person) a variety of conferences and seminars and conduct individual studies that have contributed to my professional development. These have provided me with the opportunity to share and get feedback on my research, plan for future projects/papers, network with other faculty and students, learn about new theoretical or methodological skills, and more. These include, but are not limited to, the annual meeting of the Rural Sociological Society, the International Association of Society and Natural Resources annual meeting, the WERA1010: Improving Data Quality from Sample Surveys to foster Agricultural and Community Development in Rural America annual meeting, the Rural Population Research Network/W-5001 Rural Population Change and Adaptation in the Context of Health, Economic, and Environmental Shocks and Stressors annual meeting, and a variety of seminars put on by related groups or institutions.

I have also put on training for others in the following outlets:

2022 “Diverse Rural People and Places: Social Science Approaches for Research and Outreach.” Research and Innovation Course (Dr. Sarah Franklin), *University of Utah School of Medicine*.

2022 “Sociological Approaches to Rural Research.” Rural Research Panel, *Rural & Underserved Utah Training Experience (RUUTE) Program, University of Utah School of Medicine*.

Dissemination:

While we have not shared any research results yet with community partners, we have been working with local organizations in study counties and with USU Extension agents to prepare and collect data of use to their work.

Publications Relevant to Rural Community Development and Wellbeing (including health and mental health):

Ulrich-Schad, Jessica D., Paul M. Jakus, Malieka Bordigioni, and Don Albrecht. 2022. “Preferences for Economic and Environmental Goals in Rural Community Development in the Western United States.” *Rural Sociology*. DOI: 10.1111/ruso.12429.

Ulrich-Schad, Jessica D., Jennifer E. Givens, and Mitchell Beacham. 2022. “Preventive Behaviors Along the Rural-Urban Continuum in Utah During the COVID-19 Pandemic.” *Journal of Rural Social Science* Special Issue on Space, Place, and COVID-19 37(2):4.

Ulrich-Schad, Jessica D. and Aaron Hunt. 2022. “Debunking COVID-19 Myths in Utah.” *Utah State University Extension* Fact Sheet. https://extension.usu.edu/healthwellness/research/debunking-covid-myths

Ulrich-Schad, Jessica D., Cynthia M. Duncan, and Kristen Koci. 2022. “Poverty, Health and Healthcare in Rural Communities in the United States.” Invited chapter in *The Edinburgh Companion to the Politics of American Health* edited by Martin Halliwell and Sophie A. Jones: 33-50.

Ulrich-Schad, Jessica D. and Mathew J. Barnett. 2022. “Population Growth is Related to Natural Hazard Exposure in the Rural Western U.S.” Brief # 2022-7. *Rural Population Research Network*.

Presentations Relevant to Rural Community Development and Wellbeing (including health and mental health):

2022 “Population Matters: A Symposium on Demography and Well-Being in Rural America.” Invited Moderator for Environment

2022 “Population Growth & Natural Hazard Exposure in the Rural Western U.S.” (Webinar). *Small Towns/Big Trends: Demographic Insights on Living, Working, and Thriving in Rural America*. Congressional Briefing sponsored by the Population Association of America.

Plan of Work:

We plan to continue to gather and analyze county level data on mental health and wellbeing in rural Utah and publish an extension fact sheet with the results. We have done interviews with USU Extension agents on their views of issues, resources, and barriers related to their mental health-related work and will be doing analysis with the transcripts. We have conducted nearly 50 interviews with leaders and residents in two natural resource dependent communities in the state and will be continuing to do a few via zoom and will then analyze the transcripts for themes. My PhD student working on this project also intends to finish writing and defend their dissertation using data from this project this year.

Climate Change, Media Coverage, and Societal Responses in Utah and the Intermountain West.

Project Director

Jennifer Givens

Organization

Utah State University

Accession Number

1012901



Climate Change, Media Coverage, and Societal Responses in Utah and the Intermountain West

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Accomplishments:

The overarching goals of this project are to contribute to our understanding of and assess: how the media is covering and communicating climate change, how this varies across place and time, in terms of scale, and by social, political, economic, and environmental contexts, and how this is associated with activities in response to climate change.

The specific objectives are to:

1. Collect empirical data on media coverage of climate change in Utah and the Intermountain West, including how this varies across locations and if it has changed over time.
2. Analyze statistically how variations in coverage are associated with different temporal, geographic, social, political, economic, and environmental contexts.
3. Collect data on response to climate change and test if there is a relationship between media coverage of climate change and response to climate change.
4. Develop a finer grained understanding of the determinants of and relationships between media coverage of climate change, social, political, economic, end environmental context, and response to climate change by conducting an in-depth case analysis of three local communities.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The major accomplishments from this project are many.

First, this project supported the mentorship and training of graduate students. The project supported two Master's degree

students whose Master's Thesis committees I chaired. They both earned Master's degrees in Sociology from Utah State University (USU) in 2020 and 2022 respectively. These two students collected data on media coverage of climate change in varied contexts, analyzed these data, produced successfully defended thesis projects. Their thesis projects contributed directly to each of the four goals of this project, especially objectives 1, 2, and 4.

Second, directly from these two student's thesis projects, this project has supported one published peer-reviewed article and a second article in progress. The Master's students are first authors on both the published article and the paper in progress. These papers contribute directly to objectives 1, 2, and 4.

Third, this project supported work on two additional published peer-reviewed articles (for three total published peer-reviewed articles and a fourth in progress). I am first author on one and an author on the other, which resulted from a collaboration sparked by this project. These projects more closely examine and contribute to objective 3.

Fourth, this project sparked at least five new collaborations with colleagues and indirectly fostered the mentoring of one PhD student. These collaborations resulted in the two additional peer reviewed articles mentioned above that contribute to objective 3, one of which involved the PhD student. These collaborations led to the collection of survey data in three different contexts, and access to a fourth survey data set collected by other researchers. Several of these collaborations are now ongoing.

Fifth, this project in combination with the student mentoring and additional collaborations it fostered resulted in two successful internal small grant awards at USU, a College of Humanities and Social Sciences (CHaSS) Creative Activity and Research Enhancement (CARE) project and a CHaSS Peak Summer Fellowship. These two projects supported the hiring and training of an undergraduate research assistant, providing research training to that student and mentoring experience to my Master's student. Indirectly, through one of the collaborations, this UTA project also led to a university Seed Program to Advance Research Collaborations (SPARC) project, which led to a large external grant application.

Sixth, this project supported seven accepted academic conference research presentations and the dissemination of research results, although COVID led to the cancellation of one of the presentations. Three of the presentations included graduate students as presenters.

Next, I will detail the accomplishments of this project as they directly relate to the project goals.

The first goal was to: **1. Gain a systematic understanding of how the mass media is covering climate change in Utah and the Intermountain West, including how this varies across locations and if it has changed over time.** The results of our data collection and analysis of media coverage of climate change over time from the national to local scale show that some of the standard frames used to frame climate change in the media are used consistently over time, however coverage of climate change has increased. We also find variation from the national to the local scale. For example, in ski towns in the Intermountain West, we find greater use of human-interest framing than in national coverage (Spradlin 2020; Spradlin and Givens 2022).

The second goal was to **2. Analyze how variations in coverage are associated with different temporal, geographic, social, political, economic, and environmental contexts.** Our research demonstrates that context matters. Media coverage of climate change in ski towns differs in some ways from national coverage, while in other ways it is similar (Spradlin 2020; Spradlin and Givens 2022). We also find that media coverage related to Indigenous and Native populations varies based on whether or not the media outlet itself is or is not Indigenous or Native (McCrackin 2022; McCrackin, Wilkes, and Givens in preparation).

The third goal was to **3. Test if there is a relationship between media coverage of climate change and response to climate change.** We conducted several surveys and analyzed new and existing survey data as part of this project and as part of new collaborations that this project fostered. The results of one such analysis of survey data from respondents in five states in the US Intermountain West region indicate that political economic factors shape climate change views, policy support for renewable and nonrenewable energy, and pro-environmental behaviors (PEBs); in addition, PEBs still largely occur in the realm of personal action as opposed to politically or collectively organized action (Givens et al. 2021, see also Hazboun et al. 2020). As part of these new collaborations, we continue to examine how consumption of different media shapes views on climate change, other environmental issues such the desiccation of the Great Salt Lake, and other societal issues, such as the COVID pandemic. Good research often sparks additional questions and research directions, and that is certainly the case here.

The fourth goal was to **4. Develop a finer grained understanding of the determinants of and relationships between media coverage of climate change, social, political, economic, and environmental context, and response to climate change by conducting an in-depth case analysis of three local communities.** For this part of the analysis, in one project, we analyzed

three ski towns in the Intermountain West, and in another project, we studied media coverage of climate change in both mainstream and Indigenous media at both the national and regional scales. Overall, our results are informative and nuanced and point to the importance of understanding both broad trends in media coverage of climate change and how these trends might vary or differ in very specific and particular contexts. Understanding how media coverage of climate change shapes views, policy support, and actions, and how this varies by context, is important knowledge as we work to create ways to both mitigate and adapt to climate change moving forward, both in society at large, and in specific communities in our region and beyond.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Target audiences include sociology graduate students and researchers studying media coverage of climate change and public views on the environment and climate change, public perceptions and policy support, and pro-environmental behaviors, especially in Utah and the Intermountain West. Target audiences also include scholars across disciplines that study Native American and Indigenous perspectives and several members of these communities locally.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

There were no major changes or problem. While COVID-19 affected progress at times and somewhat hindered dissemination of results at conferences and to broader audiences along the way, overall, this project was a great success.

Training and Professional Development:

As noted above, this project supported the mentorship and training of graduate students. The project supported two Master's degree students whose committees I chaired. These two students collected data on media coverage of climate change in varied contexts, analyzed these data, produced successfully defended thesis projects, and both earned Master's degrees in Sociology from Utah State University (USU) in 2020 and 2022 respectively. From the thesis projects, the students have produced one peer-reviewed article and we have another in progress, with the students as first authors. Additionally, to support our work we applied for additional internal funding from the college to support the hiring of an undergraduate research assistant to support one of the Master's student's work on this project. This provided professional development to the Master's student since she gained experience in mentoring and managing the undergraduate student, and it provided research experience to the undergraduate student, who will likely be an author on the paper we are currently preparing. In addition, the Master's students were involved in three conference presentations related to this project.

Dissemination:

There have been a total of three published peer-reviewed papers directly related to this project and a fourth paper is in progress. We also produced a white paper for the Utah State Legislature. There have been seven conference presentations related to this project. There have also been two successful, public, Master's thesis defenses with community members in attendance.

Thesis Projects and Peer Reviewed Papers Cited (* indicates graduate student author, ** indicates undergraduate student author)

Givens, Jennifer E., Shawn K. Olson Hazboun, Michael D. Briscoe*, Richard S. Krannich. 2021. "Climate Change Views, Energy Policy Support, and Personal Action in the Intermountain West: The Anti-Reflexivity Effect." *Society & Natural Resources* 34(1):99-121. <https://doi.org/10.1080/08941920.2020.1769782>

Hazboun, Shawn Olson, Peter Howe, D. Layne Coppock, and Jennifer E. Givens. 2020. "The Politics of Decarbonization: Examining Conservative Partisanship and Differential Support for Climate Change Science and Renewable Energy in Utah."

McCrackin, Gina*. 2022. "Reversing the Gaze: Using Indigenous and Western Worldviews to Compare Coverage of Climate Change and Indigenous Peoples in Compare Coverage of Climate Change and Indigenous Peoples in the News Media." Master's Thesis in Sociology, Utah State University. <https://digitalcommons.usu.edu/etd/8546/>

McCrackin, Gina*, Jennifer E. Givens, and Eric Wilkes**. In progress. "Comparing Indigenous and Western Coverage of Climate Change in Indigenous and Mainstream Media in the US."

Spradlin, Tyler*. 2020. "Framing Climate Change in Local Context: Newspaper Coverage of Climate Change In Three Mountain Towns in the Intermountain West Compared to National Coverage." Master's Thesis in Sociology, Utah State University. <https://digitalcommons.usu.edu/etd/7907/>

Spradlin, Tyler* and Jennifer E. Givens. 2022. "Framing Climate Change in Local Context: Newspaper Coverage of Climate Change in Three Mountain Towns in the Intermountain West Compared to National Coverage." *Newspaper Research Journal*. <https://doi.org/10.1177/07395329221106485>

Plan of Work:

While this project is now complete, we have one paper still in progress that we plan to send out for publication in fall 2022. This project has also sparked several ongoing research collaborations and projects.

The Rural Community Environment and Individuals with Disabilities' Social Integration

Project Director

K Christensen

Organization

Utah State University

Accession Number

1012951



The Rural Community Environment and Individuals with Disabilities' Social Integration

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The purpose of this research effort is to explore the role environmental context plays in relation to individuals with disabilities' social integration in a community.

There are numerous research questions to be explored, such as to what extent the characteristics of an individual with disabilities' environment is related with their opportunities for social interaction, quality of their social interactions, quality of their social support, self-efficacy, and perception of their quality of life. To do so the specific objectives of the research plan include:

1. Model individuals with disabilities' social environment.
2. Model individuals with disabilities' physical environment.
3. Develop an integrated framework describing the socio-ecologic environment of individuals with disabilities.
4. Describe the relationship between individuals with disabilities' physical and social environments.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The research project involved four objectives, to be completed over 5 years; (objective 1) model individuals with disabilities' social environment, (objective 2) model individuals with disabilities' physical environment, (objective 3) develop an integrated framework describing the socio-ecologic environment of individuals with disabilities, and (objective 4) describe the relationship between individuals with disabilities' physical and social environments.

The first objective occurred over the first two project years (beginning July 1st, 2017 through June 30th, 2019). These activities

represented an ongoing review of the literature necessary to develop the social and behavioral survey instruments, and IRB protocol development necessary to accomplish this first project objective. The literature review, and other efforts, led to a successful and significant external funding award to support expanded project activities. The remaining activities of the original first objective have evolved to meet the expanded objectives, which will continue to take place according to the timeline of the new research award/effort beginning September 29, 2019 through September 28, 2024. The three coordinated survey instruments, and fourth COVID-19 focused synthesis instrument, have been developed and piloted, as described in the Products section of this report. And IRB approval for their use has been obtained.

The project's original data collection activities are delayed at present due to COVID-19 pandemic impacts on individuals with disabilities' activities of daily community living. The participation of individuals with disabilities in activities of daily community living are significantly impacted by the conditions associated with responses to COVID-19. As our research team intends to collect data regarding individuals with disabilities' activities of daily community living this is a significant issue, which we needed to return to 'normal' before collecting data. Data collection began in 2022 and continues at present. In the meantime, an exploratory study was developed and conducted to assess individuals with disabilities' activities of daily community living during the COVID-19 pandemic conditions compared with those of the general population. This data, measured using an abbreviated version of the activities of daily community living instruments, both (1) informs our understanding of pandemic condition impacts (which is largely unknown at present), and (2) is being used to determine lasting impacts which may influence the project's planned data collection activities which resumed in 2022, to maintain the fidelity of the instruments. This exploratory research effort concluded mid-December 2021 and have been submitted for peer-review publication.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

The intention of the project was to explore the role environmental context plays in relation to individuals with disabilities' social integration in their communities, a population who represent approximately 19% of the total population of the United States. The outcome of this effort are validated community-scale planning practices and model policies (codes and ordinances) which may be implemented in mainstream community planning by the (dissemination target audience) planning professionals, policy makers, and advocates to support the community living and participation of individuals with disabilities (the outcomes target audience).

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Completion of the project activities is expanded as a result of the external funding award; A Socio-Ecologic Framework Supporting Individuals with Disabilities' Community Living and Participation, funded by the National Institute on Disability, Independent Living, and Rehabilitation Research, Research (NIDILRR) as a Disability and Rehabilitation Research Projects (DRRP) focused on Community Living and Participation of Individuals with Disabilities. Time commitments and timeline of the objectives have been shifted to address this expanded effort beyond the ending of this UAES project.

The UAES project's original data collection activities were delayed due to COVID-19 pandemic impacts on individuals with disabilities activities of daily community living. The participation of individuals with disabilities in activities of daily community living are significantly impacted by the conditions associated with responses to COVID-19. As our research team intends to collect data regarding individuals with disabilities' activities of daily community living this is a significant issue, with data collection resuming in 2022 when conditions returned to 'normal'.

In the meantime, the work plan was revised somewhat to emphasize other project objectives during the delay. The data collection instruments have been developed, piloted, with the intention of proceeding with pre-model development, as per Objectives 1 through 3, using the extrapolated data from piloting. These efforts facilitated the research team's recruitment and data collection efforts once the COVID-19 impacts sufficiently subsided, positioning for quick integration into the initial model development.

Additionally, and importantly, the research team initiated an exploratory study to assess individuals with disabilities' activities of daily community living during the COVID-19 pandemic conditions compared with those of the general population. This exploratory research effort has been published.

Training and Professional Development:

Under the PIs supervision two LAEP graduate student were recruited to meet the project's initial objectives. The graduate student worked actively with the PI to increase their understanding of individuals with disabilities' social networks, as well as meeting the projects objectives. A PhD student was recruited in the department of Social Work to assist in the development of the assessment instruments, including working with an advisory board of individuals with disabilities to pilot the survey instruments and work towards ensuring that these instruments reflect the characteristics and needs of the participant population of individuals with disabilities. And two PhD student in Civil Engineering participated in the project, to contribute to objective 2 through the development of an UrbanSim computational model of individuals with disabilities' community environment context, particularly in initiating the stable instance running within the project's research environment and examining the data flows among the model components.

The research team for the new funding award has recruited an additional 3 PhD and 3 masters students to assist in the expanded project objectives over the course of the next 3-4 years. As part of this expanded effort, training and technical assistance activities of the effort comprise dissemination of community-scale planning policies and practices, and tools. Instruments to assess the inclusion of individuals with disabilities in activities of daily community living, including transportation which is a critical aspect of such, represent one of these important tools. Sharing of developed resources and tools, such as these instruments, is important to improving the community living and participation of individuals with disabilities.????

Dissemination:

Dissemination has not yet taken place regarding aspects of this research project which have been delayed due to the COVID-19 pandemic. However, the exploratory studies developed and conducted to assess individuals with disabilities' activities of daily community living during the COVID-19 pandemic conditions compared with those of the general population, has been completed and disseminated;

A Double Jeopardy: COVID-19 impacts on people with disabilities' travel behavior and community living. *Transportation Research Part A; Policy and Practice*, (156): 24-35.

As have other exploratory work to establish the foundation for the research;

Impacts of disability on daily travel behavior: A systematic review. *Transport Reviews*

<https://doi.org/10.1080/01441647.2022.2060371>

A number of other articles are either in review or preparation, regarding the social sustainability of community place types, disability theory for planners, and disability-focused community policy analysis. Such as *The Role of Place Types on Social Satisfaction as Influenced by COVID and Disabilities*.

Plan of Work:

The expanded objectives related to the new award will continue beyond the ending of this project, and involve including individuals with disabilities in the computational models used in community planning and development to examine the relationships between people, housing, employment, public accommodation and services (Objective 1), and transportation (Objective 3). In a socio-ecologic framework which recognizes the link between the physical environment and the social environment (Objective 4), **we will combine these models with models of the social networks (family, friends, and acquaintances) and activities of daily community living measured through surveys with individuals with disabilities (Objective 2 – which is the original Objective 1 of the UAES project)**. Using this complex socio-ecologic model we will test whether existing community planning practices and policies (Objective 5) improve individuals with disabilities' social networks and ability to complete activities of daily living (Objective 6). Similarly, the research team will be able to develop new community planning practices. So doing will allow the research team to identify and share community planning practices and policies (Objective 8) which are likely to improve individuals with disabilities' community living and participation. The research team will conduct training and technical assistance activities to raise awareness of the available resources and assist communities in identifying those policies and practices which they may implement (Objective 9). As the socio-ecologic computational model and social networks data needed to meet the research and development objectives of this project is beyond the resources of most communities, the research team will also develop and share a user-centered socio-ecologic community infrastructure planning tool (Objective 7) which communities can use to better understand how well they currently support individuals with disabilities' community living and participation, and the effect of proposed changes in community planning practices and policies.



Certified Remote Work Professional Course

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Utah's economy experienced steady growth in recent years. However, this prosperity is not evenly distributed. In rural counties, the unemployment rate has been as high as 10%, and in most communities, the unemployment rate has more than doubled the state unemployment average of 3%. Far commutes, access to job opportunities, and automation are employment challenges facing residents in rural Utah communities. Recent challenges such as COVID-19 also impacted employment opportunities in rural communities.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The Remote Online Initiative (ROI) program was a legislative response to increasing unemployment, intergenerational poverty, and net migration of younger populations to urban centers. Led by P. Hill, the ROI program of USU Extension created the Certified Remote Work Professional (CRWP) course to provide Utah's rural workforce with education and training for online opportunities in remote employment.

Briefly describe how your target audience benefited from your project's activities.

In 2022, the CRWP's annual evaluation results (n = 101) showed that 35% of the sample found remote work, total salaries for those who found remote work increased by 73%, and 69% believed their median salaries would likely increase by 20% over the next year. With remote work, commutes to a physical workplace decreased by 62%. This resulted in an 83% total reduction in the number of miles driven by all participants who found remote work. The reduction in total miles driven equated to fuel savings of \$81 for all participants who found remote work. The reduction in total number of miles driven was equivalent to a total reduction of 0.18 metric tons of carbon emissions.

Briefly describe how the broader public benefited from your project's activities.

The Remote Online Initiative is making major progress to reduce rural unemployment by creating opportunities and implementing programs to enhance rural competitiveness and promote economic development across Utah.



Reducing Stigma Surrounding Mental Illness

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The state of Utah reported a higher rate of anxiety and depression among adults at 40.6% when compared to the national average of 30.1% (National Alliance on Mental Illness, 2021). The rate of major depressive disorders is also high in Utah, with 17.8% of adolescents 12-17 years and 9.8% of adults 18 years and older reporting at least one episode in 2019 (Kaiser Family Foundation, 2021).

In Box Elder County, 25% of county residents report experiencing poor mental health, which may have contributed to a suicide completion rate of 30.1 per 100,000 people in the county (Yaugher et al., 2020). While psychotherapy has been shown to help individuals change their emotions and behaviors (Parekh & Givon, 2019), less than half the number of individuals in Box Elder County with mental illness sought treatment (DeMoss, 2022). To reduce the stigma of mental health issues in Box Elder County, led by A. Litchford, Utah State University (USU) Extension worked to educate the public about mental illness and connect individuals with available and appropriate resources and services.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

There are two populations at high risk for suicide attempts and completions in Box Elder County. The first is adult males ages 35-44. This population had the highest suicide completion rate in Utah from 2018-2020, with 46.6 males per 100,000 completing suicide (Utah Department of Health). The second at-risk population is youth. Suicide completion is the leading cause of death for youth ages 10-24 in Utah (Utah Department of Health, n.d.). A series of activities were held to educate the public about mental health needs in the county and to connect individuals with local resources and services.

To reach the first at-risk population, adult males, Box Elder County Extension partnered with several community organizations including county commissioners, law enforcement officers, educators, and local businessmen to create short informational videos. Each video included lived experience with mental illness and ended with a message to connect viewers to local mental health resources. The videos were shared on the USU Extension county website and social media outlets. In addition, a community trap shoot event was held in partnership with a local suicide coalition and health department.

To target the second at-risk population, youth, training was provided to local 4-H leaders on the warning signs of mental health issues in youth. Leaders also received a list of resources to connect youth to local services. At a community pumpkin walk, a resource list was provided to youth and families. In addition, a women's conference was held to educate mothers and daughters on the necessity of communication in treating mental health issues. Finally, Box Elder County Extension partnered with local libraries to provide an emotional wellness workshop to children ages 2-6 years. The workshop taught children to recognize and manage their emotions by talking to a trusted adult.

Briefly describe how your target audience benefited from your project's activities.

The desired short-term outcome of this program was to increase (a) at-risk individuals' literacy of mental health issues in Box Elder County, (b) individuals' willingness to talk about these issues, and (c) connect individuals with available resources. Activities included stigma reduction videos, trap shoot events, 4-H volunteer training, pumpkin walks, and workshops.

The informational videos increased the public's awareness of mental health issues by generating 6,601 total views through Facebook, Instagram, and the Box Elder County YouTube channel. These views generated personal comments and discussion in social media posts. Some comments were, "Mental health care is just as important as any other type of care and these discussions show this. Thanks for speaking up." Another viewer said, "Great videos, thanks for being brave neighbors, faces for our own community." One individual stated, "The struggle is real! But talking is so important! We need to have more open conversations about this topic. Thank you!"

The videos also motivated eight (8) at-risk individuals to contact Box Elder Extension faculty for recommendations on services, which led to a mental health presentation at a local middle school. Additionally, three (3) male adults that viewed the videos reported having personal conversations with several at-risk individuals in need of mental health services.

The Trap-Shoot and Pumpkin Walk activities resulted in five new partnerships for Box Elder County Extension. These events led to positive outcomes by encouraging personal conversations with 25 individuals during the trap shoot activity about available mental health services. The training for the 4-H volunteers increased their willingness to talk about mental health issues with eight (8) individuals. In addition, 60 individuals took the offered resources to connect with the youth they work with to mental health services. Three additional individuals contacted the local Extension office or Box Elder County 4-H Coordinator to inquire about specific services for youth in their 4-H club.

Finally, evaluation results of the emotional wellness workshops indicated all youth participants demonstrated an understanding of concepts by verbally identifying each emotion and demonstrating breathing exercises to help calm strong emotions. Parents/caregivers also participated in the breathing exercises, demonstrating an ability to use these exercises to help their children deal with emotions.

Briefly describe how the broader public benefited from your project's activities.

Educational campaigns can be effective in reducing the negative public stigma surrounding mental health issues (Norms et al., 2016). Too often, the anxiety, depression, and emotional struggles experienced by many individuals go untreated and unnoticed because people are afraid of how friends and loved ones will react. Continuing efforts to educate the public on mental health issues can normalize the struggles of others and create an open environment for individuals willing to talk about their experiences.

Efforts by A. Litchford of USU Extension in Box Elder County will continue to address the needs of all residents, and specific programs will also be implemented for agricultural producers. A recent study suggested that two in five agriculture producers have experienced an increase in stress and worry over the past few years (American Farm Bureau Federation, 2019). Targeted efforts will decrease stigma concerning mental illness and increase access to mental health services and support in this population.



Suicide Prevention Training for Workers

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

According to the CDC, suicide among the U.S. working-age population (16-64) is trending upwards. In 2017, approximately 38,000 persons died by suicide (Peterson et. al, 2016). Suicide was selected by community partners and leaders as the top health issue in Davis County Utah for the second time; first in 2013 and again in 2018. Suicide is viewed as one of the most serious and urgent health issues in the nation (National Institute of Mental Health, 2019). It is a leading cause of mortality and morbidity, and Davis County is ranked higher than the U.S. average. Between 2015 and 2017, males account for 2 out of every 3 suicides in Davis County, and 3 out of every 4 in Utah (Utah Department of Health, 2022).

Through the Community Health Improvement Plan (2019-2023), Davis County health providers and partners developed the capacity to offer evidence-based suicide prevention and postvention programs, including *VitalCog: Suicide Prevention in the Workplace* (formerly known as Working Minds). VitalCog trains organizations to proactively address the early warning signs of suicide in the workplace, stating “just as organizations realized they can help reduce heart disease by encouraging exercise, they can also reduce suicide by promoting mental health and encouraging early identification and intervention.” Facilitated by E. Parkhurst of USU Extension, the goal of VitalCog is to educate and equip businesses with the capacity to address mental health and suicide concerns in the workplace.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

VitalCog is one of seven evidence-based suicide programs offered to the community of Davis County. Developed by the Helen and Arthur E. Johnson Depression Center (formerly known as the Carson J Spencer Foundation), the objectives of the 2-hour VitalCog training are to (a) increase awareness of suicide prevention; (b) increase capacity for dialogue and critical thinking about workplace mental health challenges, and; (c) increase organizations’ ability to promote help-seeking and help-giving in the workplace. The training builds an economic rationale for suicide prevention while promoting help-seeking and help-giving. In response to COVID-19, the VitalCog training was provided in a virtual format to avoid any disruption in program delivery.

In partnership with Davis Behavioral Health, a cohort of certified trainers led by E. Parkhurst of USU Extension provided virtual sessions in Davis County to workplace administrators and employees, Human Resources and wellness program managers, and general supervisors or managers. While this training was open to everyone, the target audience was working men since suicide rates are higher among males than females in the county. Training sessions were open to the public and provided privately for individual agencies.

Briefly describe how your target audience benefited from your project's activities.

A total of 10 virtual training sessions were conducted with 87 participants. An evaluation pre-survey was implemented before the training with a response rate of 95% ($n = 83$). Most participants were male (53%), with 47% reporting being female. Individual agencies and/or employees that completed the training include, but are not limited to, Davis School District, Layton City, Centuri Construction Group, and Children’s Service Society of Utah.

An evaluation post-survey implemented after the training had a response rate of 31% ($n = 27$). Short-term evaluation results indicated that attendees had an increase in knowledge related to suicide and suicide prevention in the workplace following the training (89%). In addition, most participants reported an improved level of confidence about talking to someone about getting help following the training (92%). Participants agreed they would be able to apply the information they learned in their place of work (88%); one of the most commonly reported concepts learned was to be direct when asking about suicide.

Participants also shared their experiences with the training: one said, “I learned the most about how to start the conversation with someone who you think might be thinking of suicide.” Another stated they learned about “the potential signs to be aware of for a suicidal person”. Lastly, a participant was made aware of the “focus it brings to the mental health and how important it

Briefly describe how the broader public benefited from your project's activities.

Evaluation results indicate an increase in employees' knowledge about suicide prevention in the workplace and confidence in talking to someone about getting help. Results also show that the VitalCog training provided employees with practical applications for suicide prevention. The positive outcomes of this training demonstrate a significant step towards reducing suicide rates within the county among the working population. USU Extension will continue the partnership with Davis Behavioral Health to target individual cities participating in Communities That Care (CTC) coalitions and construction companies within Davis County. These partnerships will enable both in-person and virtual training to increase training accessibility. It will also expand the number of trainings to other agencies outside of Davis County in partnership with the Utah Suicide Prevention Coalition.

Critical Issue

Food Safety

NC1194: Nanotechnology and Biosensors

Project Director

Anhong Zhou

Organization

Utah State University

Accession Number

7001169



NC1194: Nanotechnology and Biosensors

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

- 1) Develop new technologies for characterizing fundamental nanoscale processes and fabricate self-assembled nanostructures;
- 2) Develop devices and systems incorporating nanotechnology and data-driven analytics for detection of biological/chemical targets, with an emphasis on detection of infectious diseases in plants, animals, humans, and the environment;
- 3) Develop/improve education and outreach materials on nanofabrication, sensing, systems integration and application risk assessment

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The major technical accomplishments in this multi-state project in the past year are associated with the following objectives:

Objective #1: Develop new technologies for characterizing fundamental nanoscale processes and fabricate self-assembled nanostructures;

As a proof-of-concept, antibody-conjugated nanoprobe were constructed to specific detection of cannabinoid receptor 1 (CB1) and 2 (CB2) expressed in living neuron cell surface with the application of surface-enhanced Raman scattering (SERS) technique. By using self-assembly procedure to link the Raman reporter molecules, bi-functional agent, and antibody to the nanorods (~40 nm length x ~10 width with maximum absorbance peak at 780 nm) to form the SERS nanoprobe specific to CB1 and CB2 receptors. We conducted the preliminary test of both as-fabricated SERS probes in human neuron cells SH-SY5Y.

Objective #2: Develop devices and systems incorporating nanotechnology and data-driven analytics for detection of

biological/chemical targets, with an emphasis on detection of infectious diseases in plants, animals, humans, and the environment.

We are developing the non-invasive cell Raman spectroscopy-based technique to detect the cellular responses of diesel exhausted particles (DEPs) induced cytotoxicity and the protective effect of anti-oxidants such as resveratrol and cannabidiol (CBD) in the human cell line systems (lung cancer cell line A549 and neuronal cells SH-SY5Y). We applied a variety of machine learning-algorithms to analyze the Raman spectral data, such as principal component analysis or PCA, t-distributed stochastic neighbor embedding or t-SNE, K-means and hierarchical cluster analysis, linear discriminant analysis (LDA), multiple linear regression, principal component regression, partial least squares (PLS), knearest neighbors (kNN), support vector machines (SVM), and random forests (RF).

In addition, PI Zhou joined a collaboration with a group of researchers from 10+ land-grant universities supported by this multi-state project to publish a peer reviewed article in 2022 (see Paper#1 below).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Health department employees, dairy animal care workers, natural product developers, and cannabinoid supplement developers and manufacturers, and hemp growers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

NONE

Training and Professional Development:

Two undergraduates and 1 PhD student from PI Dr. Zhou's research laboratory in the Department of Biological Engineering were partially supported by this multi-state project. In 2022, Zhou started a new collaboration with Professor Korry Hintze from the Department of Nutrition, Dietetics and Food Sciences in the College of Agriculture and Applied Sciences. We have submitted several grant applications in 2022 (2 NIH, 1 NSF, 1 USDA).

Dissemination:

PI Zhou presented the state report in annual multi-state project meeting (August 2022). In this past year Zhou's group has published the following peer reviewed publication and delivered the conference presentations that were partially supported by this project. One paper (paper#1) was the collaboration with the researchers from this multi-state project, the other paper (paper#2) collaborated with Prof. Clay Isom from the Department of Animal, Dairy and Veterinary Sciences at USU. The undergraduate student Emily Brothersen presented her research on the antioxidant effects of cannabinoid and resveratrol on DEP-induced cytotoxicity in Utah Research on Capitol Hill in Salt Lake City on Feb 8, 2022.

Peer reviewed publications:

1.C. Yu,† P. Takhistov, †E. Alocilja, †J.R. de Corcuera, †M.W. Frey, C.L. Gomes, †Y.J. Mao. E.S. McLamore. M. Lin. O.V. Tsyusko, T.†R. J. Tzeng, †J.†Y. Yoon, †**A. Zhou**, "Bioanalytical approaches for the detection, characterization, and risk assessment of micro/nanoplastics in agriculture and food systems", *Analytical and Bioanalytical Chemistry*, 2022, 414, 4591-4612.

2.Y. Zhao, W. Zhang, B. V. Devener, T. D. Bunch, **A. Zhou***, **S. Clay Isom***,† In-situ characterization of porcine fibroblasts in response to silver ions by Raman spectroscopy and liquid scanning transmission electron microscopy ", *Talanta*, 2022, 246,

Students' conference presentations

5.E. Brothersen, A. Young, A. Zhou, "Effectiveness of Cannabinoids and Antioxidants Against Diesel Exhaust Particle-Induced Cytotoxicity using Raman spectroscopy and Machine Learning", 2022 Intermountain Biological Engineering Conference, Logan, Utah, Oct 28-29, 2022 (Poster). **(winner of Best Group Graduate Presentation award)**

4.A. Young, D. Fairbourn, A. Zhou, "Non-invasive *Cannabis sativa* genotype prediction during the vegetative growth phase using Raman spectroscopy-machine learning analysis", 2022 Intermountain Biological Engineering Conference, Logan, Utah, Oct 28-29, 2022 (Poster).

3.A. Young, E. Brothersen, W. Zhang, A. Zhou, "In vitro Analysis of Cannabidiol and Resveratrol Antioxidants Against Diesel Exhaust particle-Induced Cytotoxicity of Human A549 Lung Cells Based on Machine Learning Raman Spectroscopy", 2022 Conference on Applied Statistics in Agriculture and Natural Resources, Logan, Utah, May 16-19, 2022. (Poster)

2.E. Brothersen, A. Young, W. Zhang, A. Zhou, "Effectiveness of Cannabinoid Antioxidants Against Diesel Exhaust Particle-Induced Cytotoxicity", USU 2022 Spring Student Research Symposium, Logan, UT, April 11-15, 2022. (Poster)

1.E. Brothersen, A. Young, W. Zhang, A. Zhou, "Effectiveness of Cannabinoid and Resveratrol Antioxidants Against Diesel Exhaust Particle-Induced Cytotoxicity", Research on Capitol Hill 2022, Salt Lake City, Utah, February 8, 2022 (Poster). **(One of six undergraduates from College of Engineering were selected by USU VPR office)**

Plan of Work:

We will continue testing the agonists specific to CB1 and/or CB2 receptors expressing on human neuronal cells and the evaluation of the potential cytoprotective effect of CBD and resveratrol against cell inflammation. We will try to finish 1~2 manuscript submissions in this coming year.

Enzymatic synthesis of xylitol

Project Director

Marie Walsh

Organization

Utah State University

Accession Number

1026548



Enzymatic synthesis of xylitol

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Xylitol is a 5-carbon sugar classified as a sugar alcohol or polyol that is derived from plant xylose. It is used in the food and pharmaceutical industries as an alternative sweetener. The benefits of xylitol over other sweeteners is that it does not react with amino acids in the Maillard reaction, has a sweetening power equivalent to sucrose with 40% less calories, is anticariogenic and undergoes insulin-independent metabolism. Xylitol is currently used in chewing gum, oral hygiene products, and confectionaries. Xylitol is found in small amounts in some fruits, vegetables, algae and mushrooms, but not at a level for commercial extraction. The current commercial manufacturing method consists of chemical hydrogenation of xylose extracted from hardwood trees. This research will explore the enzymatic synthesis of xylitol from corn cob biomass using immobilized cell lysates from yeast cells housed in reactors. The goal is to use yeast cell lysates and not use genetically modified organisms or microbial fermentation systems.

Hypothesis:

Xylitol can be produced enzymatically by immobilized yeast cell lysate.

Objectives:

1. Screen yeast cell lysates grown under optimal conditions in batch systems for xylitol synthesis from xylose. These strains have been shown previously to synthesize xylitol from xylose. At least 5 different yeast strains will be used. Xylitol production will be determined spectrophotometrically. Determine xylitol synthesis as influenced by co-factor (NADH and NADPH) requirement.
2. Select two yeast strains and immobilize cell lysates for xylitol synthesis from xylose in a reactor format. Immobilize cell lysates and use in a reactor format to synthesize xylitol from xylose with predetermined co-factor. Xylitol production will be determined spectrophotometrically and confirmed via HPLC analysis. Determine the efficiency (yield) and half-lives of the bioreactors.
3. Investigate methods to degrade the hemicellulose fraction of corn cobs. Methods will include the use of dilute acids, heat, and pressure. Degradation will be determined via HPLC analysis.
4. Investigate the use of corn cob hemicellulose hydrolysate as a substrate for the immobilized yeast lysate reactors to synthesize xylitol. Determine the efficiency and half-lives of the bioreactors.
5. Explore the use of formate dehydrogenase to regenerate the co-factor in a batch system. Formate dehydrogenase will be added to the solution after xylitol synthesis. The generation of NAD(P)H will be determined spectrophotometrically.

Time Line:

This project should be completed in 5 years. It is expected that objective 1 will take 1 year to complete. Objective 2 will be initiated in year 2 will also take one year to complete. Objective 3 can be initiated in year 1 to be ready for use in year 3. Objective 4 can be initiated in year 3 and will take 2 years to complete. Objective 5 will be completed in the last or fifth year.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

This project will explore the enzymatic synthesis of xylitol using crude yeast cell lysates from yeast cells that utilize xylose to produce xylitol. Xylitol is a 5-carbon sugar classified as a sugar alcohol or polyol that is derived from plant xylose. It is used in the food and pharmaceutical industries as an alternative sweetener. The yeast strain *Scheffersomyces stipites* was grown overnight in modified yeast media containing 1% glucose and 0.5% xylose. The cells were harvested by centrifugation and grown again in modified yeast media containing 4% xylose for 4.5 hours to induce the expression of xylose reductase, the enzyme that catalyzes the conversion of xylose to xylitol in the presence of NADPH. Cells were harvested by centrifugation and lysed using Y-PER yeast protein extraction reagent. Additionally, clean silica beads (wide pore, 150 angstroms) were derivatized with 3-aminopropyltriethoxysilane and dried. The presence of amino groups on the silica beads was determined using 2,4,6-trinitrobenzene sulfonic acid. The beads were then activated with 25% glutaraldehyde for 16 hours, then washed in phosphate buffer. The yeast cell lysate was added to the glutaraldehyde activated beads and allowed to incubate for 6 hrs. The amount of protein in the cell lysate before and after exposure to the silica beads was noted and used to determine the amount of cell lysate protein immobilized. There was 10 mg protein/g silica beads. The immobilized crude *S. stipites* cell lysate (ICSCL) was then used in a bioreactor to synthesize xylitol from xylose using NADPH in tris buffer. The presence of xylitol was determined using the 3,5-dinitrosalicylic acid (DNS) reducing sugar assay since xylose is a reducing sugar and xylitol is not. Assays using 0.3 g immobilized cells with 10 mg xylose and 10 mM NADPH yielded 5 mg of xylitol. HPLC analysis of the assay determined the presence of xylose, xylitol and xylulose in the reaction. *S. stipites* growth parameters will be adjusted to maximize the amount of xylose reductase being expressed to increase the xylitol yield from ICSCL. Additionally, corn cobs were frozen in liquid nitrogen and then homogenized in a blender. The sample was then hydrolyzed with 4% sulfuric acid for 6 hours. The hydrolysate was neutralized with sodium hydroxide and this will be used as the source of xylose for the next experimental runs.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Food industry, food scientists

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

I have 1 presentation at a national meeting in 2022.

Dissemination:

I have 3 publications published in international peer-reviewed journals.

Plan of Work:

We will continue with the research outlined to investigate objective 1.

Engineering for food safety and quality

Project Director

Silvana Martini

Organization

Utah State University

Accession Number

1023580



NC1023: Engineering for food safety and quality”

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Below are the objectives of the NC1023 project. I will contribute to Objectives 1 and 2.

1. Characterize physical, chemical, and biological properties of raw and processed foods, by-products, and packaging materials.
2. Develop advanced and sustainable processing and packaging technologies to transform raw materials into safe, high quality, health-promoting, and value-added foods.
3. Develop mechanistic and data-driven mathematical models to enhance understanding and optimization of processes and products that will ensure sustainable and agile food manufacturing for safe, high quality, and health-promoting foods.
4. Adapt pedagogical strategies involving novel educational approaches to enhance and assess student learning of food engineering.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

During 2022 three main projects were performed under the UAES 1539 project. These include: (1) Evaluating the physical properties that drive oil migration in edible fats, (2) Studying the effect of CBD addition on fat crystallization, and (3) Characterizing the physical properties of chocolate samples of different origin.

Results from the first project showed that oil binding capacity (OBC) in palm-based fats was significantly correlated with SFC, hardness, G' , δ , and enthalpy suggesting that these physical properties drive OBC. Overall, these results indicate that OBC can be increased by formulating harder, more elastic fats that have high SFC and enthalpy values and low phase shift angles. The second project showed that CBD delayed the crystallization of all fats with the least effect observed for the PO. Slight increases in crystal sizes were observed with the addition of CBD for all samples. CBD did not affect the melting profile of AMF or CB but increased the peak temperature of PO and decreased the enthalpy of PKO. Similarly, hardness was only affected by CBD in PO samples with harder materials obtained for samples containing 2.5% CBD. The same trend was observed for the elasticity. In addition, the elasticity of AMF increased with the addition of CBD but not its hardness. Results from the third project showed that the yield stress increased, and the viscosity decreased with grinding time, which is consistent with prior research. It was also found that the dark chocolates had the highest viscosity, followed by the sweet dark chocolate, and then the milk sweet. These changes could be a consequence of the particle size of the chocolate and/or the content of cocoa butter.

Briefly describe how your target audience benefited from your project's activities.**Target Audience:**

The targeted audience for this project is food scientists interested in improving the quality of edible fats.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

This project provided training to one PhD student (Melissa Marsh) and two undergraduate students (Joe Cooney and Isaac Hilton). Students gained knowledge in common laboratory techniques and in more sophisticated ones such as rheology, differential scanning calorimetry, pulsed nuclear magnetic resonance, polarized light microscopy, and texture profile analysis. They also gained experience in the design and execution of experiments, in the analysis and interpretation of the results.

Dissemination:

Results from the first project were presented in the Annual Meeting and Expo of the American Oil Chemists' Society (international). A paper has been published on the effect of physical properties on OBC of soybean-based fats. A second manuscript is being prepared on the effect of physical properties on OBC on a palm-based fat. A manuscript has been accepted with the results of the second project. An abstract has been submitted with results from the third project to Research on Capitol Hill in Salt Lake City and we are planning to submit an abstract for the Annual Meeting and Expo of the American Oil Chemists' Society (international).

Below are the citations of the papers published:

1) Cooney#, J., Hilton#, I., Jones*, A., Marsh*, M., and Martini, S. 2022. Crystallization behavior of milk fat, palm oil, palm kernel oil, and cocoa butter with and without the addition of cannabidiol. Journal of the American Oil Chemists' Society (Accepted – December 2022)

2) Marsh*, M.A. and Martini, S. 2022. Relationship between oil binding capacity and physical properties of interesterified soybean oil. Journal of the American Oil Chemists' Society. 99:313-330.

Presentations:

Marsh, M. (Presenter & Author), Martini, S. (Author Only), 113th AOCS Annual Meeting and Expo, "Relationship between oil binding capacity, oil loss, and the physical properties of an interesterified palm-based fat." (2022)

Cooney, J. (Presenter & Author), Martini, S. (Author Only), 113th AOCS Annual Meeting and Expo., "Does cannabidiol affect the physical properties of anhydrous milk fat and palm kernel oil?." (2022)

Hilton, I. (Presenter & Author), Cooney, J. (Author Only), Martini, S. (Author Only), 113th AOCS Annual Meeting and Expo., "Effect of Cannabidiol on crystallization behavior and physical properties of palm oil and cocoa butter.." (2022)

Marsh, M. (Presenter & Author), Maleky, F. (Author Only), Martini, S. (Author Only), Annual Meeting of the American Association of Candy Technologists., "Fat bloom development – influence of tempering, storage, and oil migration." (2022)

Cooney, J. (Presenter & Author), Hilton, I. (Presenter & Author), Martini, S. (Author Only), Research on Capitol Hill, "What food producers need to know about cannabidiol and lipids." (2022)

Cooney, J. (Presenter & Author), Martini, S. (Author Only), Utah State University Student Research Symposium, "Does cannabidiol affect the physical properties of anhydrous milk fat and palm kernel oil?." (2022)

Hilton, I. (Presenter & Author), Cooney, J. (Author Only), Martini, S. (Author Only), Utah State University Student Research Symposium, "Effect of Cannabidiol on crystallization behavior and physical properties of palm oil and cocoa butter." (2022)

Plan of Work:

Melissa Marsh, the PhD student working in the first project will continue to collect data related to oil migration on a palm kernel-based fat. She will present her finding at the Annual Meeting and Expo of the American Oil Chemists' Society (international). The second project is finished, and no further research is planned in this topic. Joe Cooney will continue to work on the third project.

Improvement of butter functionality to use as a laminating fat

Project Director

Silvana Martini

Organization

Utah State University

Accession Number

1022989



Improvement of butter functionality to use as a laminating fat

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall objective of this project is to improve water retention in butter during the lamination process by adding a high-melting point fraction of milk fat during butter manufacture. Results from this project will allow dairy producers to manufacture high-quality butter that is sold at a premium price for lamination applications.

Specific objectives:

1. Obtain anhydrous milk fat (AMF) and high melting fractions (HMF) of milk fat from cream
2. Characterize various butter and margarine products currently in the market for their physical properties and their water retention
3. Evaluate the effect of fat content on butter quality for lamination uses.

4. Incorporate the HMF in cream and evaluate butter quality.

5. Incorporate HMF in the working step and evaluate butter quality.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

A MS student, Annalisa Jones worked on this project through 2022. During this last year Annalisa worked on 2 projects. In the first project she evaluated the effect of fat content on butter physical properties and oil loss. In this study, butter was made from cream with six different levels of fat (38%–48%). Correlation analysis showed that the fat content of the cream had a positive correlation with water loss (WL) and water content and that water loss increases with a higher fat content of cream (r : 0.918), water content (r : 0.971), enthalpy (r : 0.950), delta (r : 0.975) and a decreased G' (r : 0.826).

In the second project, Annalisa evaluated the effect of milk fat fractions on oil loss. In this study, the milk fat was incorporated to the butter using 2 methods. In the cream method AMF and AMF fractions were incorporated in the cream before churning. In the worked method AMF and AMF fractions were incorporated in the working step. AMF fractionated at 20°C, 25°C, and 30°C were used. When AMF and AMF fractions was added, the cream method resulted in samples with decreased WL with high melting AMF fractions. However, the worked procedure butters had decreased WL with lower melting AMF fractions. The cream method WL had a significant positive correlation with water content and a significant negative correlation with hardness, crossover point, solid fat content (5°C–20°C), enthalpy, and content of palmitic and oleic fatty acids ($P < 0.05$). The WL of worked method had a significant positive correlation with hardness, solid fat content at 5–20°C, and myristic fatty acids ($P < 0.05$). These findings indicate that water loss decreased with incorporation of high melting AMF fractions in the cream method and low melting AMF fractions in the worked method.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The targeted audience for this project is food scientists interested in improving the quality of butter products for use in laminated dough.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

This project provided training to one MS student (Annalisa Jones) in 2022. Annalisa gained knowledge in common laboratory techniques and in more sophisticated ones such as rheology, differential scanning calorimetry, pulsed nuclear magnetic resonance, and texture profile analysis. She also gained experience in the design and execution of experiments, in the analysis and interpretation of the results, and in writing a manuscript for publication in a peer-reviewed journal.

Dissemination:

Results were presented in local, regional, and international conference such as the BUILD Dairy Annual meeting and the Annual Meeting and Expo of the American Oil Chemists' Society (international).

Two papers have been published and a third paper is under review. The published papers are listed below:

Jones*, A. and Martini, S. 2022. Fat Content of Cream Affects the Capacity of Butter to Hold Water. International Journal of Dairy Technology 75:842-849 – doi: 10.1111/1471-0307.12887.

Jones*, A. and Martini, S. 2022. Relationship Between the Physical Properties of Butter and Water Loss during Lamination. J. Am. Oil Chem. Soc. 99:585-597.

Presentations

Jones, A. (Presenter & Author), Martini, S. (Author Only), 113th AOCS Annual Meeting and Expo, "Effect of the Fat Content of Cream on the Physical Properties of Butter." (2022)

Plan of Work:

Annalisa has graduated in Summer 2022. We are waiting for the reviewers' comments for the third manuscript.

Public Food Safety Education

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7001910



Food Preservation and Safety

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The USDA promotes home canning as a safe and budget-friendly option for preserving food. When done properly, food preserved by canning can be more nutritious compared to produce found in local grocery stores. However, if food is home-canned improperly, bacteria, viruses, and other microorganisms could grow in the food making it unsafe to eat. If consumed, this could cause food-borne illnesses which could lead to hospitalization or even death. The microorganism of greatest concern is botulism, which can be fatal if contracted. To prevent the growth of these microorganisms, individuals must follow proper canning guidelines. Cache County FCS agent receives, on average, four calls a day related to food preservation and food safety. There is a high demand for education on canning and preservation.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

J. Dyckman developed a public education program in 2022 on food preservation. The program was divided into four main components; (a) Basics of Home Canning Lecture Class, (b) Hands-on Canning Class, (c) Master Food Preserver Training Course, and (d) Phone Calls and Pressure Lid Gauge Testing.

Briefly describe how your target audience benefited from your project's activities.

The Basics of Home Canning Class targeted individuals who were new to canning, and topics included food safety, safe recipes, canning methods, and storing canned goods. A total of 78 participants attended this class. The Hands-on Canning Class provided participants with the opportunity to experience the whole canning process. In total, 29 participants attended the class. The Master Food Preserver Training Course is a 4-day training that covers all types of food preservation including canning basics, jams, jellies, fruits, vegetables, meats, pickling, salsa, tomatoes, dehydrating, freezing, and freeze-drying. Evaluation results of the food preservation classes indicated there was an increase in participants' knowledge of all concepts covered in the workshops.

Briefly describe how the broader public benefited from your project's activities.

The hands-on classes led to an increase in participants' confidence and skills to practice safe canning techniques at home. In the Master Food Preserver Training, participants demonstrated an increase in knowledge and skills to adopt proper canning techniques to safely can on their own. These outcomes can lead to a decrease in food borne illnesses and the associated



Preserve the Harvest

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Bacteria and other air particles can grow on food if not preserved accurately. These particles can grow into food-borne illnesses that can spoil food, inflict illness on individuals who eat the food or even cause death in severe cases. With a tradition of food storage in Utah, many people preserve food in their homes and use old family recipes that have not been approved by the USDA. Also, many Utahns have a large supply of stored food that may never be used mostly due to a lack of knowledge of how to incorporate it into their day-to-day meals.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

There is a need to educate individuals on how to preserve food in their homes and use food storage ingredients by using pressure canner gauges to insure canned goods are processed accurately. In 2022, M. Jewkes hosted a Canning 101 series on food canning and preservation.

Briefly describe how your target audience benefited from your project's activities.

Most participants (43.4%, n = 101) in the workshops series completed the post-course survey. Results showed 97% of participants used the food preservation resources provided, 79% explored information on USU Extension's website, 45% checked if the food preservation resources they had at home are up to date, 73% followed research-based directions provided by USU Extension and the USDA, 83% preserved food more often at home, 67% shared what they learned with other people, 21% had their pressure canner dial gauge tested, and 40% purchased additional and/or updated their preservation equipment.

Briefly describe how the broader public benefited from your project's activities.

Results suggest the food preservation education provided by USU Extension will prevent food-borne illnesses. USU Extension will continue providing these classes to residents across the state in an effort to improve the health and wellbeing of individuals and reduce the economic burden of foodborne illnesses.

Critical Issue

Global Food Security and Hunger

Improving plant nutrient availability in calcareous soils

Project Director

A Jacobson

Organization

Utah State University

Accession Number

7003045



Improving plant nutrient availability in calcareous soils

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The goals of this research are to improve nutrient use efficiency in calcareous soils through the development of novel nanofertilizers that minimize negative environmental impacts relative to conventional fertilizers, and to improve soil health in degraded, semi-arid dryland wheat fields. The specific objectives are to investigate 1) the mechanisms of novel nanofertilizer uptake into plants, 2) the fate of the nanofertilizers applied to soil that are not taken up by plants, and 3) organic P cycling and uptake from different types of compost by wheat in calcareous, organic dryland soils.

In the course of this research, we expect to develop a nano-sized phosphate fertilizer, understand its environmental fate relative to its bulk counterparts, and have a better understanding of its uptake mechanisms into the crop. We also expect to have a better understanding of which types of compost amendments are the best at improving longterm soil health at the lowest cost to growers. We expect to report our findings on a yearly basis at national meetings, and to publish our findings in peer-reviewed journals regularly.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: To investigate the mechanisms of nanofertilizer uptake into plants and how/why nutrient uptake from nanofertilizers is greater than that from their bulk counterparts.

Two undergraduate students, Lauren Bomer and Emma Khorunzhy, grew pre-germinated radish and wheat in a calcareous soil amended with metavivianite and chitosan-coated metavivianite, in a growth chamber for ten days. Metavivianite is a partially oxidized iron phosphate mineral. At the end of the growth period, they harvested the plants, digested them with concentrated nitric and perchloric acids, and had the digestates analyzed for iron and phosphate by ICP-MS. Although there was no difference in the concentration of Fe in the wheat shoots grown in soil treated with meta-vivianite, chitosan-coated meta-vivianite or Fe-EDDHA, the radish plants (dicots) grown calcareous, Millville soil in the presence of vivianite and chitosan had higher concentrations of Fe in the plant tissue than the control plants grown in Millville soil with no amendment, and radish plants grown in Millville soil grown in the presence of Fe-EDDHA (iron chelate). Iron chelate is the usual Fe amendment used to fertilize crops growing on calcareous soils. Emma and Lauren's results suggest dicot's rhizosphere acidification strategy for obtaining Fe may be more conducive to obtaining Fe from vivianite in a calcareous soil and the use of siderophores used by monocots such as wheat.

Li-Ting Yen, conducted similar research growing hard winter wheat in and amended with vivianite, chitosan-coated vivianite, Fe-EDDHA (positive control), and an unamended control in the presence of a pseudomonad bacteria, Ppf5, that produces an enzyme known to break down chitosan. Li-Ting found that more Fe is taken up by the wheat shoots in the presence of the microbe whether or not the sand was treated with meta-vivianite or chitosan-coated meta-vivianite. As much Fe was taken up by the plants treated with the meta-vivianite or chitosan-coated meta-vivianite as was in the Fe-EDDHA-treated wheat. This was true for all the plants whether they were watered with a dilute electrolyte solution or Millville soil saturated paste extract. This initial finding suggests that microbes in the soil are essential component of nutrient (Fe) cycling in calcareous soils.

Objective 2: To investigate the fate of the nanofertilizers applied to soil that are not taken up by plants.

The two summer REU students, Lauren Bomer and Emma Khorunzhy, initiated this line of research by attaching nano-sized meta-vivianite, chitosan-coated meta-vivianite and ZnO nanoparticles to aluminum stubs with carbon tape. The stubs were then buried in soil, planted with radish or wheat seed, and grown for a month in a growth chamber. Every week stubs from each treatment were removed, dried and changes in morphology and elemental surface chemistry were observed by SEM-EDS. The first week there was not much change in the samples, but by the third week morphological changes were clear. We observed a decrease in the vivianite and chitosan coated vivianite length, width and thickness, the ZnO nanoparticles changed from a spherical morphology to dendritic (star-shaped). We observed roots growing on the nanoparticles as well as nematodes. EDS confirmed that though the morphology was changing the particles were still meta-vivianite, chitosan-coated meta-vivianite, and ZnO. The students' preliminary research demonstrated that this is an effective technique for following the fate of nanoparticles in the soil. Remarkably, despite reports that ZnO nanoparticles dissolve so rapidly in soil that they cannot be detected within 24 hours, our research showed that even in watered soil with growing plants, ZnO nanoparticles were present and detectable four weeks later.

Objective 3: To investigate organic P cycling and uptake from different types of compost by wheat in calcareous, organic dryland soils.

We wrote and submitted a research proposal to USDA-AFRI in September 2022 to support this objective. A Post-doc, Idowu Atoloye has been hired starting January 4th, 2023. He will aid part-time on spring sampling for this project and train students in sampling collection and processing. Other than that, no work was completed toward this objective this reporting period.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience includes farmers, dryland farmers, organic winter wheat growers, soil scientists, soil chemists, soil microbiologists, soil fertility and soil health scientists, extension specialists, engineered nano-particle scientists.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No changes or problems occurred in this reporting period.

Training and Professional Development:

In this time period two undergraduate students (Emma Khorunzhy and Lauren Bomer) were trained grow wheat and radish plants in a growth chamber, harvest the plants and make relevant measurements of root and shoot tissues at harvest, and digest root and shoot tissues with nitric and perchloric acid for ICP analysis of element concentrations in the tissues. They also learned to prepare poster presentations for international meetings. Graduate student, Li-Ting Yen, passed her proposal defense and qualifying exam. She also taught the undergraduate students other graduate students in our extended research group how harvest the plants we are growing for the nanoparticle research.

Dissemination:

Since the results to date are preliminary, dissemination have largely been limited to our lab group and the group of researchers at USU working with metal oxide nanoparticles and wheat. The purpose is to keep everyone up to date with best lab practices so that we can refine our experiments and improve our experimental results. However, preliminary data have been presented at three international professional society meetings by the undergraduate and graduate students.

Undergraduate student, Emma Khorunzhy, presented her results in a poster on the aging of nano-metavivianite in soil at the SACNAS meetings in San Juan, Puerto Rico in October, undergraduate student, Lauren Bomer, presented her results on Fe and P uptake by radish seedlings and wheat growing in soil in a poster at the Sustainable Nanotechnology Organization (SNO) Meetings in Austin, TX in November, and Ph.D. student Li-Ting (Mila) Yen presented her results on iron uptake by wheat seedlings growing in sand amended with agronomically relevant doses of nano-metavivianite and chitosan-coated meta-vivianite in a poster at the ASA-CSSA-SSSA meetings in Baltimore, MD in November.

Products:**Presentations:**

Bomer, L. (Presenter & Author), Khorunzhy, E. (Author Only), Yen, L.-T. (Author Only), Jacobson, A., SNO 2022: Nano-scale materials and transport processes for sustainability, "Investigation of meta-vivianite and chitosan-coated meta-vivianite as a nanofertilizer," Sustainable Nanotechnology Organization, Austin, TX, USA. (November 10, 2022 - November 13, 2022)

Khorunzhy, E. (Presenter & Author), Bomer, L. (Author Only), Yen, L.-T. (Author Only), Jacobson, A. (Author Only), SACNAS: National Diversity in STEM (2022NDiSTEM), "Characterization and investigation of meta-vivianite and chitosan-coated meta-vivianite as a nano fertilizer," SACNAS, San Juan, Puerto Rico. (October 27, 2022 - October 29, 2022)

Other Products:

Audio or Video - No significant products/outputs were completed during this reporting period.

Plan of Work:

In the coming year, Li-Ting will move from growing wheat in sand amended with nano-sized meta-vivianite and chitosan-coated metavivianite to growing wheat and tomatoes in a calcareous soil amended with the same two nanoparticle amendments. Some of the plants will be salt-stressed to see if how that affects Fe uptake in the presence of the amendments.

She also hopes to complete her Ph.D.

Two REU summer students will initiate column studies to continue investigating the fate of non-target nutrient nanoparticle amendments. We also plan to submit a proposal to supplement this research.

The newly hired post-doc will supervise and train students to collect soil samples in an organic dry-land wheat field, separate-out stable aggregates in various size classes and analyze them for P, N, and C to investigate the effect of various compost amendments (soft-wood enriched, hard-wood enriched, paunch manure compost, and straw. We will also be recruiting a PhD student to work on this aspect of the project.

Investigative biochemical mechanisms controlling meat quality

Project Director

Sulaiman Matarneh

Organization

Utah State University

Accession Number

7002878



Investigative biochemical mechanisms controlling meat quality

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

OBJECTIVES:

The overall objective of this project is to better understand processes controlling the development of meat quality attributes to improve quality and reduce variation in meat products.

Objective #1: Determine the role of mitochondria in modulating the rate of postmortem metabolism and pH decline.

The working hypothesis for this objective is that mitochondria modulate the rate of postmortem glycolysis and pH decline by consuming a portion of glycolytic pyruvate.

Objective #2: Gain insight into how mitochondria-mediated oxidative stress impacts meat color stability during retail display.

The working hypothesis for this objective is that inhibition of mitochondrial oxidative stress by scavenging mitochondrial ROS improves color stability of meat.

Objective #3: Examine the biochemical mechanisms through which freezing improve meat tenderness during aging.

The working hypothesis for this objective is that freezing disrupts several cellular organelles and activates several proteolytic enzyme systems that contribute to meat tenderization.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

We have initiated research associated with objective 1 (Determine the role of mitochondria in modulating the rate of postmortem metabolism and pH decline). We utilized a modified Scopes *in vitro* model that mimics postmortem metabolism to examine the effect of inhibiting mitochondrial pyruvate utilization on the rate of anaerobic glycolysis and pH decline. We reasoned that if mitochondria metabolize glycolytic pyruvate and reduce the rate of glycolysis and pH decline, then disrupting this process would reverse those effects. This was achieved by inhibiting pyruvate dehydrogenase (PDH), the mitochondrial enzyme that converts pyruvate to acetyl-Co, and pyruvate carboxylase (PC), the cytosolic enzyme that converts pyruvate to oxaloacetate. These two enzymes play a dominant role in pyruvate utilization by mitochondria. Four treatments were tested: a

control, CPI-613 (a PDH inhibitor), avidin (a PC inhibitor), and CPI-613 + avidin. Lactate and pH were measured at different times to understand the relationship between mitochondrial pyruvate utilization and the rate of metabolism and pH decline. Treatment with CPI-613 with or without avidin lowered pH at 60, 120, 240, and 1440 min relative to the control or avidin treatments ($P < 0.05$). To confirm that the lower pH was due to greater glycolytic flux, we evaluated lactate concentrations and found that CPI-613 treatments with or without avidin had greater lactate concentrations at all-time points after the initial time point ($P < 0.05$). These data show that inhibiting mitochondrial PDH enhances glycolytic flux and pH decline, likely through increasing substrate availability for glycolysis. The rate of pH decline is one of the most significant factors affecting meat quality. Thus, it is essential that we better understand the pathways that contribute to postmortem metabolism and pH decline in order to produce meat with consistent quality.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Academics, pork producers and processor, meat scientists and students.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

Three undergraduate and two graduate students have been trained in this project.

Dissemination:

- 1- This research provided preliminary data for a USDA-NIFA foundational grant that is currently under review.
- 2- Data generated from this project were presented at national and local scientific conferences.

Plan of Work:

- 1- Complete research associated with objective 1, analyze the obtained data, and write the manuscript.
- 2- Initiate research associated with objective 2.

Improving soil health and sustainability in UTAH farming systems

Project Director

Jennifer Reeve

Organization

Utah State University

Accession Number

7002871



Improving soil health and sustainability in UTAH farming systems

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Overall Goals for sustainable farming systems studies:

- A. Improve soil health and nutrient use efficiency in organic and conventional farming systems in Utah.
- B. Determine the mechanisms associated with legacy compost effects in calcareous soils for long-term improvements in soil health and carbon storage.
- C. Explore the potential for soil management to affect soil health and carbon stocks in Utah and influence land use planning.

Specific Objectives:

- 1. Evaluate effects of soil management (compost, manure, soluble fertilizers, cover crops and intercropping) on changes in nutrient cycling, nitrogen loss, weeds, yield, quality and economics of agronomic and horticultural crops.
- 2. Determine mechanisms responsible for long-term persistence of compost in calcareous and non-calcareous dryland soils.
- 3. Assess cropping systems for soil health and carbon storage potential and develop scenarios for improved sustainability of Utah farms.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1: Improving Soil Health and Nutrient Use Efficiency in Organic and Conventional Farming Systems in Utah

The third year of phase four of my organic rotation project at Greenville was successfully completed. Winter cover crops were successful and data was collected on biomass and weeds. Dry beans and buckwheat were grown over the summer and successfully harvested. Summer crops were evaluated for weeds and biomass. This work was presented at three poster presentations at the American Society of Agronomy and SACNAS. The information generated will help researchers and growers better understand the relationship between input intensity and crop rotation on productivity in organic farming systems.

Soil quality, carbon and nitrogen storage and loss were also assessed in the organic crop rotations at Greenville. Determining how crop rotation affects soil quality and carbon and nitrogen cycling will help growers make critical management decisions that are economically viable and improve critical soil properties at the same time.

A paper on arthropod dynamics in response to organic orchard floor management was submitted for publication. Determining the potential economic viability for alternative orchard management strategies and the impacts of development pressure on orchards will help growers maintain a viable tree-fruits industry in the state.

Our efforts to develop sustainable strawberry cropping systems for the Intermountain West continued. Twelve strawberry cultivar trials were established on university and commercial farms and a second round of greenhouse trials initiated to identify strawberry cultivars that grow best on compost as a source of nitrogen. Mark Kindred started his MS degree in Soil Science on the project.

Former PhD student Andrea Clemensen published a paper from her dissertation comparing alfalfa, sanfoin and grass hay crops on nutrient cycling in soils to Crop, Forage and Turfgrass Management. Tannin containing sanfoin significantly reduced nitrate levels in the soil profile.

A paper describing the effects of compost vs manure on soil microbial communities in an organic cropping system at Greenville was published in Frontiers of Soil Science. While compost was found to increase soil microbial diversity, manure had the greater influence on microbial communities.

Four papers on various aspects of farm management on soil were published. This work resulted from participation in a national soil health assessment initiative led by the Soil Health Institute. A fifth paper assessing the suitability of a number of soil health assessment tools for evaluation of soil health in dryland cropping systems was submitted to Agroecosystems, Geosciences and Environment.

Objective 2: Determining the Mechanisms Associated with Legacy Compost Effects in Calcareous Soils for Long-Term Carbon Storage

Effects of compost additions on soil and water were assessed in dryland wheat in Snowville and Blue Creek. Former PhD student Idowu Atoloye published a paper in Soil and Tillage Research showing that single applications of compost at 50 Mg per Ha increased soil carbon up to 90 cm depth, likely attributed to increased root growth. Presentations were made to the American Society of Agronomy on the effects of compost on wheat yield and soil physical properties. Increased understanding of the mechanisms involved in long-term compost carryover will help predict when it is most likely to be cost effective to apply compost to dryland soils.

Objective 3: Exploring the Potential for Soil Management to Affect Soil Carbon Stocks in Utah and Influence Land use Planning

A major multi-state proposal was funded by the USDA Foundation for Food and Agriculture Research to evaluate the effects of cropping systems on soil health and carbon storage with Ohio State University as the lead institution. A proposal to create development scenarios and evaluate ecosystem services associated with agricultural land along the Wasatch Front was funded. A postdoc has been recruited to head up both projects in January 2023. Although delayed, MS student Anthony Whaley continued to work on comparing decision support tools for on farm soil carbon stock assessment and using biophysical landscape properties to locate the extent of potential locations that orchards could be relocated. Tools to assess the environmental, economic and cultural impact of land use change will enable the public and policymakers to make informed decisions in the face of growing development pressures.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Growers, industry, state and local government agencies, scientists and the general public interested in soil health and sustainable agriculture.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

We successfully submitted one paper started by a former student but others remain delayed. I maintain contact with former students in the hope that progress can be made in the coming year. I have decided to take on the lead of at least one of them myself in an effort to move things forward. Otherwise, there are no significant changes or problems to report.

Training and Professional Development:

This project was used to train eight undergraduate students (Abbey Lazier, Maya Schaefer-Fiello, Mark Kindred, Nate DuCasse, Daniel Rigby, Jaycee Dixon, Hannah McInnes and Natalia Bustos) in data collection, organic farming practices and outreach, three technicians (Nate DuCasse, Greg Vandas, Leanna Reynolds) in field plot maintenance, greenhouse management, sample collection and preparation and laboratory skills. In addition, one PhD student (Preston Christensen) and two MS students (Anthony Whaley and Mark Kindred) were trained in research skills, data collection, data analysis, presentation and research paper and proposal writing.

Dissemination:

No outreach presentations were given in 2022.

Other Products:

Data and Research Material - Data and crop and soil response to management.

Plan of Work:

Objective 1: The effect of winter cover crops will continue to be tested in three organic crop rotations with and without the addition of compost and manure. Soil quality and carbon and nitrogen storage will continue to be assessed at the long-term rotation plots at Greenville.

We will continue to evaluate the effects of compost and temperature on nutrient cycling and strawberry growth and productivity in high tunnels. Part of my time on this project is now funded by Western SARE.

I will help my former PhD student Mae Culumber submit the remaining two papers from her dissertation on peach tree growth and root growth in response to cover crops, and water use by cover crops in an orchard setting.

I will help my former PhD student Kristie Buckland submit the remaining research paper from her dissertation on weed competitiveness in quinoa.

Objective 2: Wheat and legume intercrops will be planted at the Snowville and Blue Creek sites and soils sampled for nutrients, soil health indicators and soil moisture. The relationship between compost type and crop and soil response will continue to be evaluated and mechanisms elucidated. At least one research paper on soil health effects of compost in dryland systems will be submitted. Part of my time on this objective is now funded by an USDA NIFA grant.

Objective 3: The relationship between farm management and soil health will be assessed on working farms in Utah and a postdoc has been recruited to head up this work. Soil carbon assessment tools will be evaluated and ground truthed for incorporating into land use scenarios for the Wasatch Front. A postdoctoral researcher has been recruited to head up this work. Anthony Whaley will defend his MS degree in the spring and submit two papers on a comparison of decision support tools for on farm soil carbon stock assessment and the use of GIS based tools for site assessment for orchards.

Integrating Orchard Management Practices to Meet Changing Needs, 2022 - 2027

Project Director

Marion Murray

Organization

Utah State University

Accession Number

7002872



Integrating Orchard Management Practices to Meet Changing Needs, 2022 - 2027

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Tree fruit plantings at the Kaysville research farm will be used to develop, test, and demonstrate new and developing integrated fruit technologies in the areas of horticulture and pest management. In addition to the UAES funding requested here to maintain orchards, additional sources of funding have and will continue to be generated to complement the research and Extension productivity. For example, the team recently received a USDA Specialty Crops and Research Initiative grant to improve the economic and environmental sustainability of tart cherry production through precision management.

Entomology Objectives

1. Test and demonstrate new pheromone and other non-chemical options for pest control of key tree fruit insect pests in Utah, including the western cherry fruit fly, codling moth, leafrollers, peach twig borer, and greater peachtree borer.
2. Monitor for established invasive insects (brown marmorated stink bug and spotted wing drosophila) as well as insect pests not yet in Utah (European cherry fruit fly, false codling moth, spotted lanternfly).
3. Test and demonstrate novel insect monitoring tools, such as new trap designs and pheromone lures for key pests of tree fruits, including new invasives.

Plant pathology objectives

1. Evaluate and demonstrate the efficacy of registered chemical and biological control products to manage fire blight in Utah.
2. Test and demonstrate the compatibility of integrated fruit management systems such as high-density orchards and orchard pruning practices with fire blight incidence.

3. Identify new plant diseases infecting Utah tree fruit.

Pomology objectives

1. Evaluate precision irrigation and fertilizer scheduling based on detailed soil mapping and utilization of management zones.
2. Compare different nursery tree types, including 1-year chip bud (industry standard), 1-year bench graft, 2-year bench graft, sleeping eye and potted “quick start” trees for establishment of a high-density apple orchard under Utah conditions.

Outreach Objectives

1. Disseminate results of research to the fruit industry at annual association conferences, field days, Extension and relevant federal and state agency meetings, the USU Extension Master Gardener course, and other appropriate opportunities.
2. Publish findings in peer-reviewed research journals, trade journals, Extension publications, newsletters, and periodicals.
3. Present results at professional meetings.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Entomology Objective 1: Monitor for established invasive insects (brown marmorated stink bug and spotted wing drosophila) as well as insect pests not yet in Utah (European cherry fruit fly, false codling moth, spotted lanternfly).

Surveys for the invasive pests, brown marmorated stink bug and spotted wing drosophila, were implemented across the state with the Kaysville orchard being one location. Traps were hung from May to October and checked weekly. Although no pests were found in 2022, growers were notified of these negative results.

Plant Pathology Objective 1: Evaluate and demonstrate the efficacy of registered chemical and biological control products to manage fire blight in Utah.

In spring of 2022, a trial on an apple block at Kaysville was conducted to test treatments for their efficacy against the bacterial disease, fire blight. Twelve treatments (either individual product, combination of products, or rotations of products) were applied to 12 trees representing three varieties. Branches were inoculated with the fire blight bacteria during full bloom (April 29), and treatments were applied on a pre-determined schedule thereafter. The percent infection was determined from the number of infected flowers out of total flowers at 4-weeks' post-inoculation.

The best performer was the standard antibiotic, streptomycin, at an average of 16% infection. The least-performing treatments were the water-treated control (average of 59% infection) and copper products (52% infection). We tested a new product, AgriPhage, which is a virus that attacks bacteria, and found poor control, at 43% infection. Most growers rely on antibiotics for fire blight, and we found promising results when using an antibiotic in rotation with other materials. For example, an early Blossom Protect (a beneficial yeast) spray followed by an antibiotic, and then another organic spray (Serenade) performed similar to the antibiotic alone, with an average of 20% infection. For growers wanting to be fully organic, we found several combinations/rotations that provided similar protection to an antibiotic, at an average of 29% infection.

Pomology Objective 1: Evaluate precision irrigation and fertilizer scheduling based on detailed soil mapping and utilization of management zones.

The drought stress studies conducted in the apple orchards at Kaysville that focused on remote sensing of irrigation water stats were concluded in 2020, and the research results were compiled and submitted for publication in 2021, but was ultimately rejected by that journal. It was determined that the initial target journal was not appropriate, and the manuscript is currently being revised for submission to a different journal in early 2023. No additional irrigation studies were conducted in 2022.

The tart cherry orchard was used to compare fertilizer type and timing under uniform irrigation. Data on tree growth and yield were collected for this experiment during the 2022 growing season. Thanks to the generous donation of a commercial cherry harvester, we were able to take detailed data on the effect of fertility program on fruit yields in this orchard.

Pomology Objective 2: Compare different nursery tree types, including 1-year chip bud (industry standard), 1-year bench graft, 2-year bench graft, sleeping eye and potted "quick start" trees for establishment of a high-density apple orchard under Utah conditions.

Plants representing a series of different nursery types and two commercial cultivars, were established during the 2022 growing season. Data collected during the reporting period was on initial survival and growth. A second set of treatments will be planted in Spring 2023, and treatments will be monitored over the next 4 growing seasons.

Outreach Obj. 1. Disseminate results to the fruit industry.

Preliminary results of project were disseminated to Utah fruit industry stakeholders at the following events in 2022: 1) Utah State Horticultural Association Annual Convention, January 20-21 (85 contacts); 2) Northern Utah Fruit Growers Meeting (26 contacts); 3) Utah Urban and Small Farms Conference, March 22-25 (virtual, 50 contacts); 4) Tree Fruit Grower Summer Meetings (sponsored by Mountainland Packing Co.), May-August, Santaquin, UT (50 contacts); 5) Utah State University Extension CEU Pesticide Education Workshop (virtual, Nov 14 and 16; 275 contacts); 6) Utah State University Extension Gardening Experts Facebook Live (online; 2,000 contacts); 7) Invasive Pest and First Detector Workshop (Sept 27; 45 contacts); and 8) USU Extension Tree Fruit Field Day, Utah County (55 contacts)

Outreach Obj. 3. Present results at professional meetings.

Results of the pathology work were shared with professional audiences at the following conferences in 2022: 1) International IPM Symposium (February, Denver); and 2) American Phytopathological Society Annual Meeting (July, Pittsburg).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Targeted audiences for dissemination of results includes fruit producers, horticulturists, fruit pest management specialists, regulatory and land management agency staff, pesticide applicators, agricultural industry professionals, extension staff, and home gardeners.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None to report.

Training and Professional Development:

The PI presented results and attended the International IPM Symposium in spring 2022 and the American Phytopathological Society Annual Meeting in summer 2022. PIs also presented at and attended the Utah State Horticultural Association annual convention; the Urban and Small Farms annual conference (virtual); and the national Entomological Society of America annual meeting.

Five graduate students (3 MS and 2 PhD) used the tart cherry orchard in their training on field plot research and remote sensing, with specific reference to orchard fertility, irrigation and heat stress management.

Dissemination:

In 2022, project updates were presented in a pest advisory newsletter to the fruit industry (reaching over 12,000), at six fruit grower meetings, five conferences/workshops, a fruit field day held in Utah County, and social media.

Products:

Nothing to report.

Plan of Work:

For plant pathology, testing of fire blight products will resume in spring of 2024 in an older orchard, as the testing orchard will be replanted and not available. We will continue to look for new plant diseases and monitoring techniques for invasive insects.

For the pomology objectives, we plan to continue the ongoing studies of differential fertilizer treatments, including tracking tree growth, yield and fruit quality. We also plan to use the orchard for continued remote sensing work, including yield monitoring, heat stress, and factors affecting fruit quality.

Quantification of the Beneficial Primary and Secondary Nutrients of Perennial Legumes Cultivated in the Mountain West

Project Director

Jennifer MacAdam

Organization

Utah State University

Accession Number

7002860



Quantification of the Beneficial Primary and Secondary Nutrients of Perennial Legumes Cultivated in the Mountain West

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The **goal** of this UAES project is to identify novel beneficial qualities of alfalfa, birdsfoot trefoil, cicer milkvetch, sainfoin and small burnet grown under dryland conditions as well as under irrigation, and to expand the plant species studied to include less-well-studied aspects of introduced and native legumes and non-legume forbs that have known or potential forage value for beef and dairy production.

The specific **objectives** of this project are to document the concentrations and nutritive value of primary nutrients and secondary metabolites in legume and non-legume forb plant species. Studies will also document germination and establishment, regrowth following harvest, and persistence over multiple years in multiple locations.

Obj. 1. Identification of components of non-fiber carbohydrates and seasonal fluctuation of alfalfa and meadow bromegrass under irrigation

Obj. 2. Determination of productivity, persistence, forage quality and tannin concentration of sainfoin cultivated under dryland conditions

Obj. 3. Productivity and accumulation of secondary plant metabolites of perennial forage legumes and non-legume forbs used to supplement perennial ryegrass-white clover irrigated pastures. We anticipate that this study will be funded through a USDA NIFA grant to be submitted in March of 2022 by Oregon State University.

Obj. 4. Productivity and accumulation of secondary plant metabolites of two dozen perennial forage legumes and non-legume forbs used to supplement grazed crested wheatgrass and similar grasses on rangeland. This study will be supported by a UAES seed grant and a USDA NIFA grant, both funded in 2021.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Obj. 1. Data for plant maturity, dry matter production and the dry matter ratio of stems and leaves were collected from alfalfa and meadow bromegrass stands established in autumn of 2019 at the Intermountain Irrigated Pasture Farm in Lewiston, UT. Plant samples were collected and freeze-dried to be used for near-infrared spectroscopy (NIRS) to determine parameters of forage nutritive value at bi-weekly intervals for the 2022 growing season, and for the composition of non-fiber carbohydrates.

Obj. 2. Data were collected from the sainfoin cultivar trial established in autumn of 2018 for the fourth and final year. In 2022 plants, were sampled 3 times – at 100% bloom and at 2 and 4 weeks post-bloom. Duplicate samples taken at each interval were either oven- or freeze-dried to determine the effect of drying on the assay of total condensed tannins. These oven- and freeze-dried samples will also be used for NIRS determination of forage nutritive value parameters, including crude protein.

Obj. 3. This Oregon State University-led USDA NIFA proposal was not funded in 2022 but will be resubmitted in 2023.

Obj. 4. Plots that had been seeded in November of 2021 on 3.5 acres at the USU Godfrey dryland farm at Clarkston, UT contained no plants of the seeded species in May of 2022, so this study was replanted. By early August, plants of eight species could be identified (sainfoin, both purple- and yellow-flowered alfalfa, small burnet, Utah sweetvetch, crownvetch, birdsfoot trefoil, and white prairie clover). By early October, plants of five additional plant species could be identified (purple prairie clover, blanketflower, showy goldeneye, Lewis flax, and cicer milkvetch). In addition to plant counts, hand weeding of Utah-listed noxious weeds was carried out as well as herbicide treatment of bindweed and prickly lettuce in the border around the plots. The plant species with the greatest numbers of plants per acre by autumn of 2022 were sainfoin (5816), small burnet (2866), Utah sweetvetch (2109) and purple-flowered alfalfa (1939). Three additional replicated studies were planted with 24 species of legumes and non-legume forbs at the USU Greenville Farm in North Logan, UT, on land owned by Snow College and used by USU Cooperative Extension in Ephraim, Utah, and on land owned by Southern Utah University and used by USU Cooperative Extension in Cedar City Utah.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience for this project is beef cow-calf producers in Utah and the northern Mountain West. Aspects of this project will be of interest to dairy producers and beef producers wishing to raise cattle to slaughter weight on pastures.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No problems have been identified so no changes in this project are anticipated.

Training and Professional Development:

The work carried out under this UAES project included training four undergraduate students to collect data in the field, process samples, and analyze collected plant material for tannins and neutral detergent fiber, and to use NIRS to determine forage nutritive value. A USU SURE undergraduate intern was also hosted in the P.I.'s lab in 2022; his project was related to Obj. 4 and carried out on his own grazing land. A master's student who will work on Obj. 4 began her studies in August of 2022. The P.I. of this project participated in a multistate project meeting in summer of 2022, and attended the annual meeting of the Crop Science Society of America in autumn of 2022.

Dissemination:

A popular press article related to Obj. 1 titled “Altitude Adds Energy Value to Alfalfa Hay” was published in the August 2022 issue of Hay and Forage Grower.

Products:

Publications:

Conference Proceedings:

MacAdam, J. W., Villalba, J., Lagrange, S., Stewart, E., Hunt, S., Legako, J., Christensen, R., Pitcher, L., & Bolletta, A. Tannins in perennial legume and forb functional forages. Proc. XXV International Grassland Congress, 14-19 May 2023, Covington, Kentucky, USA..

Villalba, J., MacAdam, J. W., Van Vliet, S., & Provenza, F. D. Integrating Plant Secondary Metabolites and Foraging Behavior to Enhance Animal Health in Beef Production Systems. Proc. XXV International Grassland Congress, 14-19 May 2023, Covington, Kentucky, USA..

Refereed Journal Articles:

Pitcher, L. R., MacAdam, J. W., Ward, R. E., Han, K.-J., Griggs, T. C., & Dai, X. (2022). Beef steer performance on irrigated monoculture legume pastures compared with grass- and concentrate-fed steers. *Animals*, 12:1017. 1329,

Other

MacAdam, J. W., & Bohle, M. (2022). Altitude adds energy value to alfalfa hay. *Hay and Forage Grower*.

MacAdam, J. W. (2022). Differential responses of irrigated grasses and legumes in the Mountain West USA to mob stocking compared with clipping. Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI..

Plan of Work:

Work will continue on all four objectives as described in my UAES project outline. For Obj. 2, sample analysis will be carried out and a publication drafted once data have been statistically analyzed.

W4112 - Reproductive Performance in Domestic Ruminants

Project Director

John Stevens

Organization

Utah State University

Accession Number

7001161



W4112 - Reproductive Performance in Domestic Ruminants

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

[W4112 Objective 1] Elucidate fundamental cellular, physiological, endocrine, and behavioral mechanisms that regulate gamete development and quality and enhance the management of reproductive function leading to development of translational reproductive biotechnologies.

- Mechanisms of ovulation and cyclicity will be elucidated in the bovine ovary using appropriate application of statistical methods to single cell RNA-seq data.

[W4112 Objective 2] Identify impacts of reproductive management, animal management and stress on follicle recruitment, ovulation, corpus luteum function, and pregnancy.

- The mechanisms by which poor maternal nutrition influences growth, metabolic pathways, DNA methylation, and liver development in F1 and F2 male and female offspring will be determined using appropriate application of statistical methods to RNA-seq and single cell RNA-seq data.

[W4112 Objective 3] Determine mechanisms regulating normal embryo development, pregnancy establishment, and maintenance by exploring maternal and paternal factors; including genomics, immune responses, fetal programming, and conceptus/uterine signaling.

- The mechanisms by which poor maternal nutrition influences growth, metabolic pathways, DNA methylation, and liver development in F1 and F2 male and female offspring will be determined using appropriate application of statistical methods to RNA-seq and single cell RNA-seq data.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

- 1) Major activities completed this year include the publication of two statistics papers (“The Academic Collaborative Statistician: Research, Training, and Evaluation”; “Handling non-detects with imputation in a nested design: a simulation study”), one animal science abstract (“Using mRNA from cytoplasmic biopsies to assess molecular maturation and developmental potential of bovine oocytes”), the training (and completion) of PhD student Rose Adjei on statistical issues related to missing and zero-inflated data, as in single cell RNA-seq data (originally motivated by a collaborative relationship with bovine reproduction researchers at UC Davis), and the training (and completion) of MS student Sydney Geisler on statistical issues relating to generalizing power approximations in a broad class of statistical models. In addition, PI John Stevens collaborated with ADVS faculty member Clay Isom and his MS student Madison Lindsey with research related to the aims of this project.
- 2) Specific objectives met this year include increasing the body of appropriate statistical methodology for agricultural genomics researchers (through the aforementioned training of the MS and PhD students as part of their finalized thesis and dissertation research), contributing to an increased understanding of the statistical issues involved in the large proportion of missing and zero-inflated data in single cell RNA-seq data, and contributing to the understanding of the basis for lower development efficiencies in embryos resulting from assisted reproductive technologies.
- 3) The following are major project findings this year:

Project 1: Zero-inflation and missing data methods for single-cell RNA-seq data

The supported PhD student (Rose Adjei) extended zero-inflation and missing data methods to single-cell RNA-seq data. This involved a new set of statistical challenges compared to traditional RNA-Seq data, but has tremendously exciting potential in understanding pregnancy and fetal development at a single-cell level. This project was motivated by collaboration with animal scientist Anna Denicol, the W4112 representative from California. A comparison of several competing statistical methods for these data found that (i) the MAGIC method consistently outperforms other methods, yielding lowest Type I error and highest power, and (ii) imputation is a critical step in scRNA-seq data analysis.

Project 2: Power Approximations for Generalized Linear Mixed Models in R

The supported MS student (Sydney Geisler) extended power approximation approaches for generalized linear mixed models, as previously implemented in SAS, to the freely-available software package R. This involved a clever application of Bayesian methods (with steep priors on variance components), and resulted in a well-documented implementation now freely available on GitHub. This will enable agricultural genomics researchers worldwide to better plan at the study design stage the numbers of replicates needed for a wide variety of study designs.

Supported Project 1: Developmental potential of bovine oocytes

Lower development efficiencies have been observed in embryos resulting from assisted reproductive technologies compared with their in vivo counterparts, but the underlying reasons are not fully understood. John Stevens provided statistical bioinformatics support on a genomic study (led by collaborator Dr. Clay Isom, with his MS student Madison Lindsey) to consider possible mRNA transcript differences between low-quality and high-quality oocytes. A preliminary set of 48 genes was considered, and (after controlling the false discovery rate) there was no evidence of differential transcript patterns between oocytes based on initial quality, even though the functional categories of the 48 genes includes apoptosis, epigenetic, metabolism, pluripotency, and RNA processing. It is important to note that this is a small preliminary set of genes, and this study established a functional framework for future research into the relationship between cytoplasmic biomolecules and oocyte quality.

Over a period of several years, John Stevens has collaborated with academic statisticians at other land-grant universities on identifying best practices for the training and assessment of academic statisticians. This previously resulted in a 2017 solo presentation at the Joint Statistical Meetings and a co-authored 2018 position paper endorsed by the Board of Directors of the American Statistical Association, regarding how Statistics should be viewed as a discipline, and how interdisciplinary statisticians should be evaluated in academia. John Stevens drew on his experiences with the interdisciplinary nature of the W4112 (and preceding versions) project to contribute to this initiative. This collaboration culminated in a 2022 publication “The Academic Collaborative Statistician: Research, Training, and Evaluation” that outlines best practices for achieving excellence as an academic interdisciplinary statistician. This deserves mention in this report because such statisticians (especially those working with agricultural collaborators as do all of the co-authors on these works) are part of the target audience for the W4112 audience.

4) The following are the main impacts of this project this year:

- * We characterized a mechanism to identify potentially differentially expressed genes between low- and high-quality bovine oocytes.

- * We characterized (in work by Rose Adjei) the various methods currently used for dealing with high missingness and zero inflation in single-cell RNA-seq data.

- * We empowered researchers to better design studies in order to achieve best statistical power in generalized linear mixed models.

- * We established best practices for the training and evaluation of interdisciplinary statisticians, especially those working with agricultural collaborators.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience of this project is the community of agricultural genomics researchers, with a focus on those working in domestic livestock reproduction, as well as on the agricultural statistics community supporting such genomics research.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report.

Training and Professional Development:

This project supported two graduate students this year: Rose Adjei (completed PhD student) and Sydney Geisler. This support allowed both students to present at the Conference on Applied Statistics in Agriculture and Natural Resources. The principal investigator also attended the Research Advances in Agricultural Statistics meetings and Joint Statistical Meetings, where he networked with other researchers working in areas relating to this project.

Dissemination:

The results of this project have been disseminated through a combination of the following this year:

- [1] publications (one animal science abstract and two statistics papers published)

- [2] graduate student MS thesis (Geisler) and PhD dissertation (Adjei)

- [3] discussions at conferences (Research Advances in Agricultural Statistics, Joint Statistical Meetings)

Products:

Publications:**Conference Proceedings:**

Adjei, R., & Stevens, J. R. (2022). Handling non-detects with imputation in a nested design: a simulation study. Conference on Applied Statistics in Agriculture and Natural Resources.

Refereed Journal Articles:

Sharp, J. L., Griffiths, E. H., Bridges, W. C., Hanford, K. J., Craig, B. A., & Stevens, J. R. (2022, December). The Academic Collaborative Statistician: Research, Training, and Evaluation. *Stat*, *11*(1), e483. 1294,

Other:

Lindsey, M., Liu, Y., Cuthbert, J., Stevens, J. R., & Isom, S. C. (2022). Using mRNA from cytoplasmic biopsies to assess molecular maturation and developmental potential of bovine oocytes. (2nd ed., vol. 35, pp. 235-236). Reproduction, Fertility, and Development.

Presentations:

Stevens, J. R., Annual Meeting of the Utah Chapter of the American Statistical Association, "The Future of Statistics in the Data Science Universe." (October 2022)

Geisler, S. (Presenter & Author), Stevens, J. R. (Author Only), Conference on Applied Statistics in Agriculture and Natural Resources, "Power Approximations for Generalized Linear Mixed Models in R Using Steep Priors on Variance Components." (May 17, 2022 - May 19, 2022)

Adjei, R. (Presenter & Author), Stevens, J. R. (Author Only), Conference on Applied Statistics in Agriculture and Natural Resources, "Handling Non-Detects with Imputation in a Nested Design: A Simulation Study." (May 17, 2022)

Plan of Work:

The principal investigator will continue collaborations with animal science researchers employing gene expression technologies (such as RNA-Seq) to better understand mechanisms underlying successful establishment of pregnancy and fetal development – including Clay Isom (USU ADVS), Heloisa Rutigliano (USU ADVS), Kristen Govoni (UConn), and Anna Denicol (UC Davis). The principal investigator will also mentor a new PhD student (Maha Moussa) on research following up on issues from the Adjei research, regarding the extension of zero-inflation and missing data methods to single-cell RNA-Seq data (which involves a new set of statistical challenges compared to traditional RNA-Seq data, but which has tremendously exciting potential in understanding pregnancy and fetal development at a single-cell level).

NC1195: Enhancing nitrogen utilization in corn based cropping systems to increase yield, improve profitability and minimize environmental impacts

Project Director

Jeanette Norton

Organization

Utah State University

Accession Number

7001179

**NC1195: Enhancing nitrogen utilization in corn based cropping systems to increase yield, improve profitability and minimize environmental impacts**

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The long-term goals of this regional project are to better understand how the interactions of soil, weather, climate, and cropping system influence N availability and optimal N management from all N containing inputs. Additionally, we plan to develop tools that help farmers translate this understanding into practice. Over the next five years, we aim to develop one key new piece of knowledge and/or one new management tool that moves N management toward reduced environmental impact while maintaining production benefits. The ultimate success of the project- reduced N loss, efficient N fertilizer use and continued increase in crop yield - lies in grower adoption of N recommendations and management practices developed. This will require a thorough understanding of how practices within a cropping system impact N availability and yield, understanding the producer and adviser decision making process, and development/enhancement of decision tools that will inform N fertilization decisions. Thus, a strong, transformative extension education/outreach program targeted to producers and crop advisors (in conjunction with extension educators, local/state/federal regulatory personnel, and policymakers), is central to this project.

Objectives:

- 1) Determine the roles of innovative management practices, the environment, and their interactions on optimum use of nitrogen in agroecosystems.
- 2) Understand the role of soil biological processes in controlling plant available nitrogen and their relationships with soil health and system resilience.
- 3) Translate field and laboratory research into nitrogen management decision-making tools and educational resources promoting improved profitability and sustainability of corn-based cropping systems.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Ongoing field study on silage corn in a semi-arid environments was maintained and sampled for soil characterization and microbial community. New aspect of this study was to investigate vetch as a post-season cover crop in silage corn with a focus on soil N cycling parameters. Vetch biomass estimates were approximately 3000 kg dry matter/ha at 3.9% N for approximately 110 kgN/ha in aboveground plant biomass. Assuming 50% available would suggest that the cover crop contributed approximately 55 kgN/ha to the corn. Vetch contribution was not significantly different based on previous fertility treatments.

Summer research experience for undergraduate students sampled vetch shoots and roots with nodules before termination and investigated nitrogen fixing bacteria from these samples. Several nodule occupants were isolated and chosen for draft genome sequencing. All were closely related to *Rhizobium leguminosarum*. Refinement of sequences and further characterization of biological N fixation by vetch cover crops continues.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

students, scientists, extension

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Collaborative 1195 work summary: Results of this research will make cover crop integration more successful in corn-based cropping systems and avoid excess N fertilizer application when cover crops are implemented. - The emerging relationships between soil health indicators and the economic optimum N rate will help to advance soil testing to improve the precision of N fertilizer management. - Understanding how management practices such as irrigation method and cover crop use affect N₂O emissions will inform strategies to reduce the carbon footprint of agriculture. - Online nitrogen cycling educational materials enable current and future agricultural practitioners to make more informed N management decisions.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report.

Training and Professional Development:

J. Norton recieved additional experience on ways to use soil carbon and nitrogen information to relate to soil health.

Dissemination:

Presented at Multi-state project meeting (virtual) and at SSSA meeting in 2021

Publications:

Refereed Journal Articles:

Habteselassie, M. Y., Woodruff, L., Norton, J. M., Ouyang, Y., & Sintim, H. (2022, September 24). Changes in Microbial Communities in Soil Treated with Organic or Conventional N Sources. *Journal of Environmental Quality/ Wiley*.

Plan of Work:

Continue in coordination with UAES project and doctoral work of Phearen Miller

Development of Improved Winter Wheat and Winter Barley Cultivars for Utah

Project Director

Margaret Krause

Organization

Utah State University

Accession Number

7001831



Development of Improved Winter Wheat and Winter Barley Cultivars for Utah

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

This project aims to address the need for high-yielding, disease-resistance cultivars of winter wheat and winter barley that are adapted to dryland and irrigated conditions in Utah. The project aims to leverage emerging methodologies include aerial high-throughput phenotyping and genomic selection to identify superior cultivars for release. These cultivars and information on their regional performance will be disseminated to growers, seed producers, industry representatives, and other stakeholders.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Genomic prediction methods were applied to assist in the selection and promotion of breeding materials within the program during the 2022 season. This methodology enabled greater maintenance of genetic diversity.

A variety description for submission to the *Journal of Plant Registrations* and a Plant Variety Protection application has been prepared for the release of a new six-row spring feed barley to be called 'Rulon'. These materials will be submitted upon receiving approval from the Utah Agriculture Experiment Station variety release approval board, which will be convened in early 2023.

Three elite six-row winter feed barley breeding lines (UTWB10406-9, WB11135-1, WB11135-2) have been identified as having high potential for release. Breeders seed plots of all three were sown in the fall of 2022. All three entries were sown in the 2022–2023 University of Idaho Extension Variety Trials.

Briefly describe how your target audience benefited from your project's activities.

The target audience includes wheat and barley breeders from the Western United States, wheat and barley producers from Utah and Idaho, and industry stakeholders involved in seed production, milling, and baking. Dissemination of information from this project has resulted in a change in knowledge for our target audience. Growers and stakeholders were made aware of the upcoming release of 'Rulon' during Utah State University Extension Crop Schools in 2022. Once the seed becomes available for growers for purchase, it is expected that growers may switch to producing Rulon because of the benefits it provides (high yields, plump grain, low lodging).

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

A major challenge encountered was that the project's full-time technician left his job at the end of July. The project was without a full-time technician until a new technician started at the beginning of October. This delayed the analysis of data and dissemination of results.

Training and Professional Development:

Four graduate students joined the project to receive training in plant breeding and genetics during 2022: Will Krause, Dalton Jones, Claire Spickermann, and Gulfam Riyasat. Will Krause graduated with a B.S. from Truman State University. Dalton Jones earned a B.S. from Weber State University. Both enrolled at Utah State University in the spring semester of 2022 and are pursuing M.S. degrees in Plant Science. Dalton is conducting research on aerial HTP for selection at the headrow, and Will is evaluating GS approaches for predicting dwarf bunt resistance in wheat. Claire earned a B.S. from California Polytechnic State University and an M.S. from University of California Davis. Gulfam received a B.S. from the University of Sargodha and an M.S. from the University of Agriculture in Pakistan. Both enrolled at Utah State University in the fall semester of 2022 and are pursuing Ph.D. degrees in Plant Science. Claire is evaluating HTP approaches for improving grain and forage yield in intermediate wheatgrass in collaboration with the USDA Forage and Range Research Laboratory, and Gulfam is developing a research project related to drought tolerance in wheat.

The program provided training in field- and laboratory-based plant breeding and research skills to five undergraduate students: Vivien Hansen and Kylie Hansen (pursuing B.S. degrees in Plant Science), Kyle Jeppesen (pursuing a B.S. in Agricultural Business), Garrett Richardson (pursuing a B.S. in Mechanical Engineering), and Tyler Dayley (pursuing a B.S. in Integrated Studies).

The project received a seed grant from the Agricultural Genome To Phenome Initiative (AG2PI) to host an in-person workshop to provide hands-on training in aerial HTP for plant breeding and research. With co-instructors from the University of Florida and the University of Illinois–Urbana Champaign, the project hosted the training workshop at the Utah State University Kaysville Education Center on February 19–23, 2022. A total of 23 attendees representing 13 institutions 12 states attended the workshop.

Dissemination:

Breeding trial results and variety release information was disseminated through oral presentations to wheat and barley growers at Utah State University Extension Crop Schools in Cache County, Weber/Davis County, and Box Elder County, UT during the spring of 2022. Breeding and research activities were shared with breeders and researchers of the Western Wheat Workers in Pendleton, OR on June 21st, 2022 through an oral presentation; with the United States National Association of

Wheat Growers and the United States Wheat Associated on November 8th, 2022 via a virtual presentation; and with breeders and researchers in attendance of the ASA–CSSA–SSSA International Annual Meetings on November 8th, 2022 through an oral presentation.

Products:

Other Products:

New Germplasm - The project produced F1 seed of 10 dryland winter wheat crosses, 7 irrigated winter wheat crosses, and 12 winter barley crosses. The project also produced seed of 110 new F5:7 dryland winter wheat lines, 56 new F4:6 irrigated winter wheat lines, and 56 F4:6 winter barley lines.

Data and Research Material The project recorded yield data for the following: 1144 plots (388 entries) of dryland winter wheat at 5 locations; 160 plots (60 entries) of irrigated winter wheat at 1 location; 180 plots (70 entries) of winter barley at 1 location; and 330 plots (165 entries) of spring wheat at 1 location. Other agronomic data (e.g., plant height, days to heading) and basic grain quality information (e.g., protein, test weight) was collected for all of these plots. High-throughput phenotyping data (i.e., unmanned aerial vehicle-captured imagery, canopy temperature, chlorophyll concentration) was collected for approximately 80 percent of these plots. Dwarf bunt disease resistance data was collected on 3800 plots (3094 entries). Genotyping-by-multiplex sequencing was applied to 196 dryland winter wheat and 60 irrigated winter wheat elite breeding lines, returning genotypic information for 953 genome-wide markers. Malting quality data was collected for 5 elite winter barley breeding lines. Baking quality data was collected for 135 elite winter wheat breeding lines.

Plan of Work:

The 6-row spring feed barley variety 'Rulon' will be released in 2023 following the acquisition of Plant Variety Protection and publication of a description in the *Journal of Plant Registrations*. Information about this variety will be disseminated to growers through oral presentations at the Utah State University Extension Crop Schools during early 2023 and through a field day in Blue Creek, UT during the summer. Breeders seed of a selected 6-row winter feed barley will be harvested and sown in the fall of 2023 for the production of foundation seed.

Breeding trials for dryland winter wheat, irrigated winter wheat, and winter barley were greatly expanded for the 2023 season. In the fall of 2022, 1361 dryland winter wheat plots were planted across 7 locations (compared to 1144 plots at 5 locations in the previous year), 310 irrigated winter wheat plots were planted across 2 locations (compared to 160 plots at 1 location in the previous year), and 366 winter barley plots were planted at 3 locations (compared to 180 plots at 1 location in the previous year). These will be evaluated for grain yield, other agronomic traits, HTP traits, and grain quality in 2023.

During the 2023 growing season, both the HTP and dwarf bunt research experiments that were carried out in 2022 will be repeated. Following the collection of a second year of data, the final analyses will be conducted, described, and submitted for publication in a scientific journal.

Beneficial wheat root-colonizing bacteria responses to abiotic stresses: Biofilm architecture and outer membrane vesicle roles in plant health.

Project Director

David Britt

Organization

Utah State University

Accession Number

1026565



Beneficial wheat root-colonizing bacteria responses to abiotic stresses: Biofilm architecture and outer membrane vesicle roles in plant health.

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective 1: Employ a root mimetic system and quantify the effects of a plant watering status and NP stress on *PcO6* biofilm architecture. An arrayed hollow fiber platform will be developed in the first six months. The artificial root exudates (AREs) that feed into the root-mimetic will be defined during this time period as well.

Objective 2: Isolate outer membrane vesicles and test their roles in the rhizosphere through application to planktonic and biofilm *PcO6* cultures. OMV isolation through standard gradient ultracentrifugation will be conducted during year-1, with additional isolation processes advanced in year-2, including tangential flow filtration, to improve OMV yields.

Objective 3: Isolate outer membrane vesicles and test their roles in the rhizosphere through application to wheat (*Triticum aestivum*, var. Juniper). This objective will be conducted once OMV isolation processes are advanced and yields are scaled up to provide sufficient OMV quantify for delivery into the rhizosphere. It is anticipated that this will yield fundamental insight into inter-kingdom signaling between rhizo-colonizing bacteria at the plant host.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Four primary accomplishments were obtained for this period:

1. A new wheat endophyte was isolated, purified, and expanded into freezer stocks. Phenotype corresponds to bacillus based on colony morphologies at growth plates, atomic force microscopy imaging of individual bacteria: size and membrane topography corresponding to bacillus; arrangement of bacteria into chains of with bifurcations to form "y-shapes". Preparations for ribosomal RNA analysis prepared.
2. The beneficial wheat root colonizing Gram negative bacteria, *PcO6*, was re-isolated from wheat seedlings grown from surface sterilized seeds in sterile sand. The isolates produced a strong orange pigment corresponding to phenazines, and growth on iron-deficient media resulting in production of fluorescent pyoverdine. A new freezer stock from this re-isolated and purified *PcO6* was prepared.
3. The ability of *PcO6* to form biofilms and produce secondary metabolites (phenazine, pyoverdine) on agar growth media prepared with increasing levels of salinity was tested. NaCl concentrations were 0%, 2%, 4%, 6%, and 8% (m/v) with electrical conductivity (EC) values of 0.00952, 32.02, 58.17, 71.26, and 109.7 (ds/m) respectively. The *PcO6* was able to grow on the salt agar growth plates up to 4% salinity, albeit with reduced colony size and reduced pigmentation, corresponding to severe salinity and abiotic stress.
4. The response to *PcO6* to an agricultural excipient / wetting agent (a nonionic triblock copolymer Pluronic F68) was characterized, demonstrating that *PcO6* does not utilize F68 as a carbon source. At the macroscopic level F68 transitioned *PcO6* colonies from round to dendritic as F68 concentration was increased. On the microscopic level, fluorescently labeled F68 was demonstrated to adsorb/absorb on/in *PcO6*. Atomic force microscopy revealed no changes in the lipopolysaccharide patterning of the cell membrane by the F68 exposure. In mammalian cells we observed F68 selectively partitioning to the mitochondria, suggesting this excipient has membrane targeting activity. This may have implications for wetting agents / excipients in agriculture.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Biological engineering, biology professionals

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

The new Ph.D. student (Anagha Wankhade) working on this project was trained in all of the microbiology and imaging methodologies necessary to conduct this work. A visiting Ph.D. student from the University of Tehran, Iran, was trained in microbiology, microscopy, and plant growth techniques.

Dissemination:

Two poster presentations at the regional Institute for Biological Engineering Conference (IBEC) in October, 2022.
One oral presentation at the Sustainable Nanotechnology Organization annual conference in November, 2022.

Products:

Publications:

Book Chapters:

Anderson, A. J., Britt, D. W., & Dimkpa, C. (2023). Nano-microbe interaction and implications for soil health and plant vigor: dialogs in the rhizosphere. *Nano-enabled sustainable and precision agriculture*. Elsevier

Refereed Journal Articles:

Hortin, J., Anderson, A. J., Jacobson, A., Britt, D. W., & McLean, J. E. Modifications in wheat shoot and rhizosphere metabolites by drought and microbial root colonization. *Frontiers in Plant Science*.

Presentations:

Anderson, A. J. (Presenter & Author), Jacobson, A., McLean, J. E. (Author Only), Britt, D. W. (Author Only), Korean Plant Pathology Program, "Nanoparticles and their future in agriculture," Seol. (October 2018 - Present)

Zargaran, M. (Presenter & Author), Wankhade, A. (Author Only), Anderson, A. J. (Author Only), Britt, D. W. (Author Only), Institute of Biological Engineering Conference (IBEC), "Potential benefits of adjuvant Pluronic F68 in agriculture," IBE, Utah State University. (October 28, 2022 - October 29, 2022)

Wankhade, A. (Presenter & Author), Zargaran, M. (Author Only), Anderson, A. J. (Author Only), Britt, D. W. (Author Only), Institute of Biological Engineering Conference (IBEC), "Understanding The Associations Of Plants With Bacterial Colonizers," IBE, Utah State University. (October 28, 2022 - October 29, 2022)

Britt, D. W. (Moderator), Jacobson, A., McLean, J. E., Anderson, A. J., Cartwright, A., Deakin, J., Potter, M., Sparks, D., Gordon Research Conference: Nanoscale Science and Engineering for Agriculture and Food Systems, "Nanoparticle Activity in the Wheat Rhizosphere," GRC, Southern New Hampshire University. (June 19, 2022 - June 24, 2022)

Britt, D. W. (Presenter & Author), Jacobson, A. (Author Only), McLean, J. E. (Author Only), Anderson, A. J. (Author Only), Cartwright, A. (Author Only), Kjar, A. (Author Only), Vargis, E. (Author Only), Gordon Research Conference: Nanoscale Science and Engineering for Agriculture and Food Systems, "Transitioning Excipients from Medicine to Agriculture -- Bioactive NP Capping," GRC, Southern New Hampshire University. (June 19, 2022 - June 24, 2022)

Other Products:

Physical Collections - A *Bacillus* endophyte was isolated and purified from the wheat (*Triticum aestivum* var. Juniper, 2020 harvest)

Plan of Work:

The outputs from this reporting period provide two plant-associated bacteria (one wheat endophyte, one root-colonizing epiphyte) that will be examined in the next year. Communication mediated by volatile metabolites and outer membrane vesicles (OMVs) between these bacteria will be investigated. The endophyte may provide signals that support PcO6 root

colonization, and the two microbes may impart a combined benefit to the host plant. Single and mixed microbial biofilms will be constructed and the architecture and ability to withstand abiotic stress (e.g. salinity) will be investigated.

Evaluation of Commercially Available Genomic Testing to determine applicability in the selection of female replacements and bull power in Utah Cattle

Project Director

Matthew Garcia

Organization

Utah State University

Accession Number

1026645



Evaluation of Commercially Available Genomic Testing to determine applicability in the selection of female replacements and bull power in Utah Cattle

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The first objective of the current project is to utilize and validate currently available genomic tests being offered to Utah producers to increase the accuracy of selection in beef heifers. The second objective is to utilize currently available genomic testing to evaluate bull traits and to determine which bulls are integrating their genetics into herds, and how many calves each bull is producing every season to better estimate bull power and increase accuracy of selection of retained heifers from those matings.

The specific aims for the project are:

Specific Aim #1: Utilize and validate commercially available genomic tests that claim to increase accuracy of selection for heifers with longevity in Utah beef populations.

Specific Aim #2: Utilize and validate commercially available genomic tests on bulls being utilized in multiple bull breeding pastures in the Intermountain West.

Specific Aim #3: Adjust selection indexes to more accurately weight valued traits in an Intermountain West breeding system.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

1. Genotyped 86 new animals on the igenity beef profile for longevity
2. Parentage tested 130 calves from two operations to determine actual bull power and to associate phenotypes with bull genetic predictions.
3. Published a peer manuscript detailing the use of GPS technology and parentage testing to increase accuracy of selection for bull power.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Utah beef producers looking to increase accuracy of marketing or selection cattle.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Drought has impacted our ability to find producers that are retaining ownership or feeding cattle to finishing. We have addressed this issue by identifying collaborators that consistently have conducted this practice and plan on doing so in the future.

Training and Professional Development:

n/a

Dissemination:

The results of this work was presented at multiple extension programs. Specifically, the beef educators program not only used these results to educate producers on the capabilities of commercial genomic testing, but it was also used to foster new collaborations.

Plan of Work:

We have identified new collaborators that retain ownership on approximately 400 head of cattle a year. We plan to commercially test these animals prior to feedlot shipping to sort them into "carcass quality" pens based on genomic testing results. We will then compare final carcass measurements to determine how accurate current genomic tests are for commercial cattle.

Evaluation of novel tree fruit and tree nut germplasm for potential commercialization

Project Director

Teryl Roper

Organization

Utah State University

Accession Number

1026569



Evaluation of novel tree fruit and tree nut germplasm for potential commercialization

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The objectives of this project are to: Complete genetic analysis of the almond collection compared to accessions at the USDA germplasm repository from Central Asia. Continue to evaluate the remaining germplasm for fruit/nut quality and for adaptation to the Intermountain West. Evaluate the self-fruitfulness of four almond individuals that may be released into commercial trade. Continue evaluation of putative salt tolerant apple rootstocks.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

During 2022 we made significant progress at meeting the project objectives. Objective 1 has been revived. Genetic analysis of the Thatcher, Utah collection compared to the USDA germplasm repository materials in California shows almost complete genetic overlap. Almonds from a defunct northern Utah nursery are similar to Nonpareil, but distinct from the materials from central Asia. Culinary evaluation of the remaining almonds, peaches, filberts, and apricots is complete. While some of the peaches are excellent, they are not as good as commercial cultivars that have been planted in the orchard. None of the apricots have quality even approaching hardy commercial cultivars planted in the orchard. No almonds were set on branches in the exclusion bags. Companion branches had excellent fruit set. We have completed the evaluation of novel apple rootstocks in salty environments (Tintic) compared to a non-salty soil (Kaysville). All rootstocks grew better at Kaysville than at Tintic. We had high tree mortality at Tintic compared to Kaysville.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Commercial and amateur tree fruit and nut producers in the Intermountain West.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

The commercial orchard in Goshen was sold so we had to abandon our apple rootstock planting at that location.

Training and Professional Development:

Information has been shared with grower audiences in Utah.

Dissemination:

A Material Transfer Agreement was signed between USU and Stark Brother Nursery. USU provided Stark Brothers Nursery with budwood from four almond selections and they have budded many trees of each of the four selections to peach rootstocks in both 2021 and 2022. We are currently working with USU Technology Transfer Services to license these four almond selections for commercial introduction. Stark Brothers Nursery was also provided with photographs of the trees and nuts for use in their spring 2023 catalog. Negotiations appear to be nearing completion. Data on the apple orchards was shared with the USDA apple rootstock breeder at Cornell University.

Publications:

Refereed Journal Articles:

McCord, P., Singh, V., Kaundal, A., & Roper, T. R. Genetic diversity of new almond accessions from Central Asia and cold-adapted North American germplasm.

Other Products:

New Germplasm -

Variety 1: This is a medium sized tree producing large nuts (2.7 grams in the shell) with hard shells. Kernels average one gram. Nuts are oval and equal in shape. The tree produces sweet kernels. Flowers have very pale pink to white petals. Flowers are not self-fruitful. Flowering is with or slightly earlier than peach. Fruit mature in late September. The tree grew from a seed collected in Bostanlik, Uzbekistan and is a half-sibling to 30S-24.

Latin name: Prunus dulcis

Common name: Almond

Variety 2: This is a medium sized tree producing large nuts (3.46 grams in the shell, kernels, 1.6 g) with hard shells. Nuts are oval and equal in shape. The tree produces sweet kernels. Petals are white and showy. Flowers are not self-fruitful. Flowering is with or slightly earlier than peach. Fruit mature in late September. The tree grew from a seed collected in Bostanlik, Uzbekistan and is a half-sibling to 30S-23.

Latin name: *Prunus dulcis*

Common name: Almond

Variety 3: This is a slightly larger than medium sized tree producing large nuts (2.1 grams in the shell) with soft shells that can be easily removed without tools. Kernels average 1.2 grams. The tree produces sweet kernels. Petals are white with reddish centers. Flowers are not self-fruitful. Flowering is with or slightly earlier than peach. Fruit mature in late September. The tree grew from a seed collected in Tashkent Province Uzbekistan and is a half-sibling to 36S-5.

Latin name: *Prunus dulcis*

Common name: Almond

Variety 4: This is a slightly larger than medium sized tree producing large nuts (1.8 grams in the shell) with soft shells that can be easily removed without tools. Kernels average 1.14 grams. The tree produces sweet kernels. Petals are white with reddish centers. This is a vigorous tree that grows well given adequate nitrogen and water. Flowers are not self-fruitful. Flowering is with or slightly earlier than peach. Fruit mature in late September. The tree grew from a seed collected in Tashkent Province Uzbekistan and is a half-sibling to 36S-4.

Latin name: *Prunus dulcis*

Common name: Almond

Plan of Work:

The plan of work is being followed

Genomic mechanisms of host range expansion in *Callosobruchus maculatus*

Project Director

Zachariah Gompert

Organization

Utah State University

Accession Number

1026576



Genomic mechanisms of host range expansion in *Callosobruchus maculatus*

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall objective of this project is to characterize the genomic mechanisms by which the cowpea seed beetle, *Callosobruchus maculatus*, is able to feed on new crop hosts, especially lentil (*Lens culinaris*). This insect is native to Africa, but is now cosmopolitan and consists of variable host races or biotypes that differ in their ability to attack particular grain legumes. There is evidence that colonization of novel hosts has facilitated the geographic spread of this species, which is still expanding. I will use genomic analyses of multiple seed beetle populations and experimental selection lines to elucidate the genetic changes that mediate the expansion of this pest's host range. A key focus of this work is to determine how hybridization facilitates host-range expansion.

I will work towards this goal by pursuing three specific objectives. The first two objectives focus on how hybridization and introgression facilitate host expansion, whereas the third objective involves identifying the specific gene variants needed for persistence on lentil.

1. Characterize the genomic basis of adaptation to lentil in *C. maculatus* with and without hybridization

2. Compare patterns of adaptive evolution in *C. maculatus* hybrids on an ancestral (cowpea) and novel (lentil) crop host

3. Create introgression lines to identify the gene variants allowing persistence of *C. maculatus* on lentil

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Progress has been made on all three specific objectives of this project. Activities and accomplishments for each goal for this first year are described below.

1. Characterize the genomic basis of adaptation to lentil in *C. maculatus* with and without hybridization

We extracted DNA from 889 *C. maculatus* beetles from 30 lentil selection lines. This includes 15 non-hybrid lines (five replicates each from Burkina Faso [BF], Brazil [BZ], and California [CA]) and 15 hybrid lines (five replicates each of BFxBZ, BFxCA, and BZXCA), with ~20 beetles from each of one (non-hybrid) or two (hybrid) time points (i.e., generations). We completed partial genome sequencing of these individuals using our genotyping-by-sequencing approach. These DNA sequence data have been aligned to the *C. maculatus* reference genome and variable nucleotides (SNPs) have been identified. Analyses of these data are underway to identify regions of the genome associated with adaptation to lentil in the hybrid and non-hybrid lines. Additional pooled whole-genome sequencing was completed this year for 10 of the beetle lines. These data will provide more fine-grained information on the genetic changes associated with adaptation to lentil. We finished DNA sequence alignment and variant calling for these data as well. Lastly, we have conducted long-read DNA sequencing using the Oxford nanopore platform for a subset of lentil adapted lines. While analyses of these data are ongoing, we have already identified an abundance of large structural genetic changes (e.g., chromosomal inversions and large deletions) that could contribute to adaptation.

2. Compare patterns of adaptive evolution in *C. maculatus* hybrids on an ancestral (cowpea) and novel (lentil) crop host

We completed DNA extractions for an additional 579 hybrid *C. maculatus* beetles maintained on the ancestral host, cowpea. This includes ~20 beetles from each of five replicates and two time points for each of the three hybrid line combinations: BFxBZ, BFxCA, and BZXCA. We have also completed partial genome sequencing of these samples and have aligned these DNA sequence data to the *C. maculatus* reference genome and identified SNPs. Analyses of these data are also underway to distinguish between two causes of selection in hybrid lines, that is host adaptation versus purging of incompatibility loci in hybrids.

3. Create introgression lines to identify the gene variants allowing persistence of *C. maculatus* on lentil

We created five replicate introgression lines for fine mapping of loci allowing *C. maculatus* to adapt to lentil. These lines have experienced >4 generations of backcrossing and selection in lentil. We completed DNA extraction and partial genome sequencing for these introgression lines. Preliminary analyses are underway with these data to verify that a sufficient number of generations of backcrossing have passed to localize genetic variation allowing for the persistence of *C. maculatus* on lentil. We have also obtained structural genetic variant data for these lines using Oxford nanopore sequencing.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience served by this project includes other researchers working on plant-insect interactions, plant breeders, and researchers and practitioners in pest (insect) management.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No major changes are planned at this point, and we have yet to encounter problems with our design.

Training and Professional Development:

Two graduate students in my lab have received training through this project. This includes training in insect rearing (animal husbandry), modern molecular lab methods (including nanopore DNA sequencing), and computational data analysis and bioinformatics. An undergraduate student (Alia Donely) received similar training by helping with this project. This culminated in an honors thesis for Alia.

Dissemination:

Several manuscripts are in preparation and research talks are planned for this summer, but thus far the results of this project have not been presented to the public or scientific community (we are still in the early stages of the project).

Plan of Work:

During the next reporting period, we expect to complete the tests for selection in hybrid and non-hybrid lines for objectives 1 and 2 based on the combination of our partial and complete whole genome data and the long-read DNA sequence data. We expect to submit manuscripts describing these results for publication. Depending on the results of our initial DNA sequencing experiment with the introgression lines, we will likely either conduct additional sequencing of these lines or conduct additional rounds of backcrossing (if haplotype blocks are still too large to identify individual genes under selection).

Identifying Management Options for Invasive Grass Control in Pasture and for Protection of Rangeland Restoration Seedlings from Invasive Annual Grass Re-Invasion

Project Director

C Ransom

Organization

Utah State University

Accession Number

1026571



Identifying Management Options for Invasive Grass Control in Pasture and for Protection of Rangeland Restoration Seedlings from Invasive Annual Grass Re-Invasion

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

- 1) Adapt approaches developed by this program for invasive annual grasses management in range to address invasive grass management in pasture.
- 2) Determine strategies for using residual herbicides on seeded desirable grass and forb species at restoration sites to protect them from reinvasion by invasive annual grasses.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The trial established in the fall of 2021 was evaluated for species establishment. Wile plant counts were taken early spring, extreme drought conditions caused mortality of all seeded species. Data analyzed for the Utah DNR on establishment efforts was analyzed and prepared for presentation by the graduate student directly associated with this project. Research plots

established in 2021 were reseeded and a new seeding was planted in the fall of 2022. Greenhouse trials were also established to look at the effect of indaziflam rate and band width on germination of Siberian wheatgrass and small burnet. Further trials will evaluate carbon bands in an attempt to protect seedlings from the preemergence herbicide. Additional data on long-term invasive annual grass research trials was collected and is being analyzed. My weed research program generated over \$178,9610 dollars in 2022 to support critical research on weed management.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences include farmers, ranchers, small acreage landowners, and public land managers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Seedings done in 2021 failed to establish in 2022 due to drought. Plots were reseeded in fall 2022. A nursery site and sites to evaluate foxtail barley management were not identified in 2022 due to land availability issues and drought conditions.

Training and Professional Development:

Across the weed science research program, training was provided for three graduate and two undergraduate students during 2022. Students gained experience in field and greenhouse research techniques as well as data collection and analysis. Graduate students were also given opportunity to present their research at a regional professional meeting.

Dissemination:

Information was presented at 32 different extension type meetings including 13 County Crop Schools. Presentations included those to practitioners, students, and colleagues. I was author or co-author on 12 presentations presented at the Annual Conference of the Western Society of Weed Science.

Products:

Publications:

Conference Proceedings:

Beckley, C. J., & Ransom, C. (2022). Evaluating Control Options for Knapweed in Utah. (vol. 75, pp. 63-64). Proceedings of the Western Society of Weed Science.

Creech, J. E., & Ransom, C. (2022). Burndown Herbicide Options for Dormant Alfalfa. (vol. 75, pp. 45). Proceedings of the Western Society of Weed Science.

De Stefano, A., Mealor, B. A., Rew, L. J., Mangold, J., Ransom, C., Jones, L. C., & Prather, T. S. (2022). Effects of Introduced Annual Graminoids on Native Vegetation of Rangelands Across Northwestern United States. (vol. 75, pp. 68-69). Proceedings of the Western Society of Weed Science.

Fowers, B., Mealor, B. A., Ransom, C., Clark, S., Sebastian, D. J., & Nissen, S. J. (2022). Effects of Indaziflam Application Timing on Annual Grass Control at Seven Rangeland Sites. (vol. 75, pp. 74). Proceedings of the Western Society of Weed Science.

Fronk, N. L., & Ransom, C. (2022). Identification, Distribution, and Management of Elongated Mustard. (vol. 75, pp. 38). Proceedings of the Western Society of Weed Science.

Fronk, N. L., & Ransom, C. (2022). Management Challenges for Garlic Mustard in Forest Understories. (vol. 75, pp. 63). Proceedings of the Western Society of Weed Science.

Gunnell, K., Landeen, M. L., & Ransom, C. (2022). Considerations in the Use of Herbicides for Annual Grass Control in Degraded Arid and Semi-arid Rangeland Restoration. (vol. 75, pp. 65). Proceedings of the Western Society of Weed Science.

Hettinger, E. M., Ransom, C., & Monaco, T. (2022). Targeting Different Life Stages of Dyer's Woad with Various Herbicides and Timings. (vol. 75, pp. 36-37). Proceedings of the Western Society of Weed Science.

Maughan, P. W., Ransom, C., Buell, H., & Quicke, H. (2022). Fluctuations in Precipitation as a Driver of Response to Invasive Annual Grass Management. (vol. 75, pp. 36). Proceedings of the Western Society of Weed Science.

Thiemann, D., Ransom, C., & Creech, J. E. (2022). Inter-seeded Cover Crop Performance for Competitive Suppression of Weeds and Invasive Kochia in Small Grains Crops in the Intermountain West. (vol. 75, pp. 89-90). Proceedings of the Western Society of Weed Science.

Thiemann, D., Ransom, C., & Creech, J. E. (2022). Understanding Water Utilization in Irrigated Spring Wheat and by Inter-seeded Cover Crop, Dynamite Red Clover. (vol. 75, pp. 48-49). Proceedings of the Western Society of Weed Science.

Zesiger, C., Ransom, C., & Drost, D. T. (2022). Efficacy of Various Preemergence Herbicides for Season-long Control of Puncturevine in Pumpkin. (vol. 75, pp. 76-77). Proceedings of the Western Society of Weed Science.

Refereed Journal Articles:

Freundlich, G., Schaeffer, R., Tebeau, A., Black, B. L., Ransom, C., Alston, D. G., & Reeve, J. (in press). Organic orchard floor management in peach: effects on arthropods and associated fruit injury in the Intermountain West. *To appear in Journal of Ecological Entomology*.

Roberts, C., Yost, M., Ransom, C., & Creech, J. E. (2022). Oat companion seeding rate, herbicide, and irrigation effects on alfalfa establishment. *Agronomy Journal*.

Plan of Work:

Data will be collected from trials established or reseeded in 2022. Further trials on medusahead management will be established in 2023. The areas for seeding and screening of desirable species tolerance to herbicides will be established and sites to conduct foxtail barley research will be identified.

LIFE HISTORY RESPONSE TO ENVIRONMENTAL CHANGE IN WILD BEES

Project Director

Karen Kapheim

Organization

Utah State University

Accession Number

1026568



LIFE HISTORY RESPONSE TO ENVIRONMENTAL CHANGE IN WILD BEES

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The goal of this project is to expand knowledge about how bees respond to environmental change.

Objective 1. Survey life history trait investment across a broad range of bees

Objective 2. Evaluate how social and ecological factors correspond to variation in life history traits within species

Objective 3. Experimentally assess how bees adjust their investment in life history traits in response to changing environmental conditions

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishment:

1) Major activities completed:

Obj 1: My students and I have completed a field season surveying the cellular response to an immune challenge in solitary and social bees. We also measured the external antimicrobial response in select species. We will evaluate how internal and external immunity are correlated within and across species. This field season allowed us to work out some methodological issues, and establish a protocol for use in future field seasons.

Obj 2: We have completed experiments showing that increasing temperature leads to increased aggression in *Halictus rubicundus*. We will follow up these experiments to see how this corresponds to physiological state, including immunity. We have analyzed RNA sequencing data to understand the molecular basis for variation in immunity in a solitary species, *Nomia melanderi*.

Obj 3: We have not yet begun working on this objective.

2) Specific objectives met:

Obj 1: This objective has been partially met.

Obj 2: This objective has been partially met.

Obj 3: This objective has not been met.

3) Significant results achieved, including major findings, developments, or conclusions (both positive and negative):

Obj 1: We have begun to contribute to a change in knowledge regarding the immune function of several bee species.

Obj 2: We have begun to contribute to a change in knowledge regarding how the physical and social environment influence immune response within species.

4) Key impacts or other accomplishments realized:

Obj 1: We have developed new methods that can be used to assess bee immunity from several aspects.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The results of this work will be of interest to the scientific community interested in reproductive development in bees, bee health, insect physiology, and social behavior. These results will also be of interest to stakeholders in the agricultural system, including crop growers, seed companies, and bee managers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

This project has involved one-on-one mentoring of one post-doc, two graduate students, and two undergraduate researchers. Mentoring has involved training in field and laboratory techniques, as well as building communication skills in the form of presentation and grant proposal writing.

Two graduate students presented research at an international conference – IUSSI 2022 in San Diego, CA.

One undergraduate student is completing his Honors Capstone Thesis project after work on this project. He presented his preliminary results at the USU Biology Undergraduate Research Symposium.

I have recruited another graduate student who will begin working on this project in 2023.

Dissemination:

The preliminary results have been presented at the International Union for the Study of Social Insects meeting in three different presentations, including one invited presentation.

Kapheim, K. M. (2022) “Mechanisms of life history shifts associated with social evolution in bees”, *International Union for the Study of Social Insects Congress*, San Diego, CA; Organizers: S. Rehan, A. Toth, S. Sumner.

Weinstock, R. A., Kapheim, K. M. “Investigating the plasticity of bee social behavior under climate change” *International Union for the Study of Social Insects Congress*, San Diego, CA (2022) – poster

Hunter, F. K., Kapheim, K. M. “Investigating the dynamics of bee immune responses and their relationship with social behavior” *International Union for the Study of Social Insects Congress*, San Diego, CA (2022) – poster

Preliminary results have also been presented at the USU Biology Undergraduate Research Symposium.

Stoker, C., Kapheim, K. M. “Protein nutrition and immunity in male bumblebees of *Bombus impatiens*” *Utah State University Biology Undergraduate Research Symposium* (2022) – poster

Other Products:

Data and Research Material - We have completed an additional field season to collect data on cellular and external immunity of bees.

We have completed a lab experiment to collect data on cellular immunity of bumble bees.

Protocols - We have developed and refined a protocol for measuring bee immunity using the encapsulation response. We have tested this protocol with many bee species.

Plan of Work:

During the next reporting period, we will continue experiments to meet Objectives 1 & 2. These experiments will be in Panama at the Smithsonian Tropical Research Institute and in the SW US probably at the Southwest Research Center. We will develop protocols for measuring nutrient stores across bee species to correlate with immunity. We will also continue to identify the bee species we have already assayed with DNA barcoding and morphological identification. We will begin experiments designed to address Objective 3.

Spear Growth in Asparagus: Improved Harvest Prediction Models

Project Director

D Drost

Organization

Utah State University

Accession Number

1026560



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The primary goal is to better predict spear emergence and growth in asparagus. This will be accomplished by:

First, evaluating the role of soil temperature (T_{soil}) on asparagus bud break (growth resumption). The specific questions include: 1) what are the optimal soil temperature requirements for bud growth, and 2) once growth resumes, how does soil temperature affect spear elongation and the interval between spear initiation or harvest?

Second, is there a dormancy period in asparagus, and how does it impact bud break and spear growth? Specifically to: 1) assess chilling durations on bud break? 2) evaluate chilling temperatures on bud base temperatures? and, 3) how growing temperatures impact spear elongation?

Third, to use the information collected in Obj. 1 and 2 to improve existing spear growth models. The models of interest include: 1) identification of base temperature values, 2) chilling and heat unit parameters, and 3) use these to improve predictive growth models for asparagus.

Fourth, to provide asparagus researchers, educators, growers, and industry representatives with the needed information to create conditions that optimize spear production. Since asparagus grows for many years, a better understanding will help them program production, schedule labor, and manage markets.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Work in 2022 focused on asparagus growth response to temperature.

Objective 1 (evaluate the role of soil temperature on asparagus bud break): work continues on evaluation of temperature (2, 5, 8, 11, 14, 17, 20C) on bud break and spear elongation. Spears emerge at all temperatures except 2C suggesting triggering temperature for bud break is close to 5C. As temperature increased from 5-14C spear growth rate increased linearly. At 17 and 20C, rate of spear elongation was not different from each other.

Objective 2 (dormancy in asparagus and its impact bud break and spear growth): Crowns and plants are grown in a greenhouse, moved to field and returned to greenhouse. Plants in greenhouse were acclimated then moved to cold rooms set at 2C, 5C, or 10C. Plants exposed to temperatures for 3 or 6 weeks then moved back to greenhouse to evaluate time to bud break and spear growth rate. Gathered data showed there was not difference in the initiation of bud break or spear elongation rates for any of the temperatures evaluated. Data suggests there is no requirement for chilling to encourage spear growth (bud break or elongation). Additional verification work continues with larger plants. Work on Annual Asparagus continues with site re-establishment and growth monitoring in summer 2022. Plants will be harvested in spring 2023.

Objective 3 (improve existing spear growth models): Additional field environmental data (temperatures throughout asparagus root profile) to be collected in winter/spring of 2023. Need more data to model heat flux and transfer and verify spring 2022 models used to predict spear emergence. Changes in temperature with depth will help verify bud emergence predictions gathered from growth chambers. Field findings suggest that about 250 growing degree days needed for spears to emerge from soil. Data used to estimate spear emergence (initiation) and growth starting in March 2023 in high tunnels and in the field grown asparagus in Apr. 2023.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Key audiences include asparagus researchers and asparagus growers across North America. Other groups targeted: cooperative extension specialists, county extension staff, state (Dept. of Agriculture and Food), and Federal (NRCS, Risk Management) agencies interested in asparagus production information, at the local, regional, and national levels.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

Attended the 15th International Asparagus Symposium (Cordoba, Spain; June 2022) to share findings from our studies with the asparagus research community. Member of the scientific committee (paper selection and review), student paper (oral/poster) judging committee member, and presented paper on Josh Martin's (MS student) research findings. Paper submitted and accepted for publication. Title: "High Tunnel Production for High Yields: Options for Established and Annual Asparagus".

Dissemination:

Shared findings with the Utah/Regional (western) /National Vegetable Growers.

1) Pennsylvania (Feb. 1, 2022) Mid-Atlantic Fruit and Vegetable Conference. Attendance: 80 people. Talk title: "Asparagus CHO Management and High Tunnel Production Strategies for High Yield"

2) Utah (Feb. 23, 2022) Utah Small Farms Conference. Attendance: 75 persons. Talk title: "Low Tunnels, High Tunnels, and Shade – Systems to Enhance Specialty Crop Productivity".

3) Colorado (Feb. 28, 2022) Colorado Fruit and Vegetable Conference. Attendance: 45 persons. Talk title: "Low Tunnels, High Tunnels, and Shade – Systems to Enhance Specialty Crop Productivity".

Products:

Presentations:

Drost, D. T., Martin, J., International Asparagus Symposium, "High Tunnel Production for High Yields: Options for Established and Annual Asparagus.," International Society for Horticultural Sciences, Cordoba, Spain. (June 12, 2022 - June 15, 2022)

Drost, D. T. (Invited Lecture), Colorado Fruit and Vegetable Conference, "Low Tunnels, High Tunnels, and Shade – Systems to Enhance Specialty Crop Productivity," Colorado Fruit and Vegetable Growers Association, Denver, Colorado. (February 28, 2022)

Martin, J. (Presenter Only), Drost, D. T. (Author Only), Urban and Small Farms Conference, "Annual Asparagus – Preliminary Assessments," Utah State University Cooperative Extension, Virtual. (February 23, 2022)

Drost, D. T. (Invited Lecture), Mid-Atlantic Fruit and Vegetable Conference, "Winter/Summer Cover Crop Options Influence Vegetable Productivity in Irrigated Systems," State Horticulture Association of Pennsylvania, Hershey, Pennsylvania. (February 2, 2022)

Drost, D. T. (Invited Lecture), Mid-Atlantic Fruit and Vegetable Conference, "Asparagus Carbohydrates and High Tunnel Production for High Yields," State Horticulture Association of Pennsylvania, Hershey, Pennsylvania. (February 1, 2022)

Other Products:

Data and Research Materiale Data collection in 2022 from growth chamber, greenhouse, and high tunnel/field settings.

4) Utah (Mar. 24, 2022) USU High Tunnel Field Day. Attendance: 60 persons. Talk title: “Low and High Tunnel Enhance Asparagus Crop Productivity”.

5) Spain (Jun. 12-15, 2022) 15th International Asparagus Symposium. Attendance: 85 asparagus researchers from around the globe. Poster title: “High Tunnel Production for High Yields: Options for Established and Annual Asparagus”.

6) Utah (Oct. 21, 2022) Graduate School Exploration Day. Attendance: 40 prospective graduate students from regional universities. Talk title: “Opportunities in Vegetable Research – Asparagus”.

7) Michigan (Dec. 6, 2022) Great Lakes Fruit and Vegetable Conference. Attendance: 90 persons. Talk Title: “Asparagus Crop Management and Alternative Production Strategies for High Yield”.

Individual consultations with an asparagus grower in New Jersey who is implementing some of our work on his farm

Plan of Work:

Spear emergence (initiation) and growth work continuing in greenhouse/growth chamber settings (Jan-Apr 2023). Refining growth models and using new information to verify earlier findings. We will share 2022 findings with Utah vegetable growers, extension personnel, and industry leaders at Utah Small Farm Conference in March. Continue to work with graduate student (Josh Martin) as he finalizes his asparagus research (Yr. 2 yields, etc.) on Annual Asparagus Production Systems. Thesis and manuscript preparations, finalize extension bulletins and budgets. I will share more details on ongoing studies with Utah farmers at the Urban and Small Farms Conference (Feb. 24, 2023). Use that opportunity to collect survey information from growers about interest and integration into existing farm operations.

Facilitating Registration of Pest Management Technology for Specialty Crops and Specialty Uses

Project Director

C Ransom

Organization

Utah State University

Accession Number

1026694



NRSP4 - Facilitating Registration of Pest Management Technology for Specialty Crops and Specialty Uses

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Facilitate registrations of crop protection products on specialty food crops and minor uses.
2. Provide regulatory support to assist public sector scientists and small business achieve pesticide registrations with new technology
3. Develop product performance data needed to support registration of chemical and bio-based pesticides on environmental horticulture crops
4. Cooperate with various domestic and international partners to harmonize global pesticide registration standards for specialty crops

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Food Use: During the duration of this project the Western IR-4 program has received hundreds of requests for minor crop pesticide uses. These requests have been reviewed by state Liaisons and by commodity representatives and then prioritized based on the most critical needs. During 2022 there were 22 current efficacy trials and 59 tolerance trials. Projects for 2022 include some crops important to Utah including caneberry, cherry, peach, grasses, grass seed, hemp, and mint. Also during

2022, five pesticides successfully received tolerances from EPA on numerous specialty crops. This program benefits Utah by providing specialty crop producers needed solutions for pest management.

2. Ornamental Program: Summaries of 12 specific products and the trial results were posted to the National IR-4 webpage in 2022.

3. Biopesticides Program: No new biopesticide trials were listed in 2022.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Specialty crop producers and producers with pesticide needs that are not currently available.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None.

Training and Professional Development:

Once again in 2022, the meeting of the Western IR-4 State Liaisons and representatives of the Crop Liaison Committee was held virtually.

Dissemination:

The role this program plays in meeting critical needs for pesticide registration in minor crops has been presented at various extension meetings and has been communicated when specific calls on pesticide use and/or needs are personally received. Another presentation was given to the Utah fruit growers on options for controlling herbicide resistant kochia.

Plan of Work:

Continue to review minor crop pesticide needs in Utah and communicate those need to Western IR-4.

Specialty Crops and Food Systems: Exploring Markets, Supply Chains and Policy Dimensions

Project Director

Kynda Curtis

Organization

Utah State University

Accession Number

1025781



S1088: Specialty Crops and Food Systems: Exploring Markets, Supply Chains and Policy Dimensions

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Analyze the relative benefits and costs for fruit, vegetable, and other specialty crop farmers of:

a) the adoption of production and processing practices (e.g., organic, biodynamic farming, adaptation to climate-extremes) and novel technologies at the field level (i.e., mechanical harvesting, biodegradable plastics, gene-edited varieties) that address both the changing production environment and the consumer preferences and needs that will be explored in Objective 2; and

b) government and industry-led programs aiming to address consumer preferences and needs while guaranteeing the viability of farm businesses (e.g., certifications, plastic pollution regulations, Farm Workforce Modernization Act).

2. Investigate the policy and market factors that affect the demand for fresh and value-added specialty crop products, including consumer understanding, perceptions, and behavioral response to non-conventional systems of agri-food production (e.g., organic, biodynamic, hydroponics, vertical growing), and the production and processing practices, and some of the novel technologies explored in Objective 1; commodity and regional marketing programs; voluntary labeling schemes (e.g., Fair Trade, Bee Friendly Farming, SIP Certified, geo-identified, integrated or “stacked” labels); product country of origin; international trade, food safety incidents and food safety risk-reducing practices (e.g., traceability systems), among others.

3. Identify drivers and implications related to the use of various specialty crop marketing channels at the local, regional, national and international scales, including profitability of participation by farmers and intermediaries; benefits and costs for consumers and communities to participate; impacts of various sources of risk and uncertainty; the role of institutional marketing innovations; presence and impacts of market power; implications of supply chain management practices; resiliency of supply chains to shocks; and costs and benefits of policies that impact specialty crop marketing channels.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

My research and outreach on this project applies to Objective 2.

Objective 2: Investigate the policy and market factors that affect the demand for fresh and value-added specialty crop products, including consumer understanding, perceptions, and behavioral response to non-conventional systems of agri-food production (e.g., organic, biodynamic, hydroponics, vertical growing), and the production and processing practices, and some of the novel technologies explored in Objective 1; commodity and regional marketing programs; voluntary labeling schemes (e.g., Fair Trade, Bee Friendly Farming, SIP Certified, geo-identified, integrated or “stacked” labels); product country of origin; international trade, food safety incidents and food safety risk-reducing practices (e.g., traceability systems), among others.

Accomplishments for 2022 include:

Local foods marketing, farmers’ markets and agritourism:

Ongoing research and outreach in this area included three webinar presentations on the impact of inflation on consumer pricing and producer input prices. One journal article was drafted and will be submitted in February 2023. One academic presentation was done on covid-19 based resiliency for agritourism enterprise and another on DEAI in agritourism. One conference proceeding paper on resiliency was published. One book chapter on DEAI in agritourism funding is forthcoming as well as one conference proceedings paper. One journal article on Senior Farmer’s’ Markets was published, and another submitted for review.

Organic Wheat Marketing Study:

A wheat quality needs assessment was conducted with organic wheat buyers (millers and bakeries) using two separate online surveys. One journal article was published based upon these results.

A survey of wheat growers (both organic and non-organic) was developed and administered in 2021/2022. We are currently analyzing results and expect at least one journal article and two Extension fact sheets will be written and reviewed in 2023.

A survey of US consumers on preferences and WTP for organic bakery products was conducted in the fall of 2021. Based upon the results three journal articles have been drafted, one is under review, and the two others will be submitted in January 2023.

Two Extension fact sheets were written and will be submitted for review in 2023. One paper was presented at an academic conference in October 2022.

A webpage for all publications, including Extension and outreach materials for this project with regards to marketing and producer adoption components can be found at: <https://extension.usu.edu/apec/organicwheatmarketing>.

Organic Strawberry Marketing Study:

A new grant to fund this project was approved in 2021 WSARE for \$350K. We are evaluating consumer taste preference and willingness to pay for organic strawberry varieties under production in the study. The research design and experimental methods have been fully developed. The field and lab experiments will be conducted spring to fall 2023.

Local Cut Flower Marketing Study:

Early study components included a survey of florists in fall of 2021 and 2022. Survey results were presented at the Utah Urban and Small Farms Conference in February 2022 and at an academic conference in October 2022. One conference proceedings paper is forthcoming. A grant to fund further project research and outreach was submitted to WSARE in November 2022.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Production enterprises (primarily) and buyers or consumer households. Production enterprises include trade organizations, individual producers, packers, distributors, shippers, and retailers, with some attention to the regulatory agencies, certification organizations, and community organizations that support those producers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

One post-doc is working on these projects.

One graduate student is working on these projects.

Dissemination:

See accomplishments above.

Publications:

Book Chapters:

Curtis, K., Hagerman, A., & Tropp, D. (in press). Overcoming institutional discrimination in USDA programs: Rural and agricultural tourism. *Inclusion in tourism: Understanding institutional discrimination and bias*

Conference Proceedings:

Curtis, K. (in press). Understanding and Enhancing Diversity, Equity, Access, and Inclusion in Agritourism: Innovative Research and Outreach in Entrepreneurship. Proceedings of the 2022 International Workshop on Agritourism.

Curtis, K., & Stock, M. (in press). Growing a New Cut Flower Industry: Market Needs & Preferences. Journal of Food Distribution Research.

Curtis, K., & Slocum, S. (2022). Firm Resiliency Post Economic Shock: A Case Study of Rural Wineries During the COVID-19 Pandemic. Journal of Food Distribution Research.

Drugova, T., & Curtis, K. (in press). The Impact of Taste Beliefs on Consumer Perceptions of Organic Specialty Bakery Products. *Journal of Food Distribution Research*. 1502,

Refereed Journal Articles:

Drugova, T., & Curtis, K. Do consumers care about organic when consuming specialty bakery products or is it all about indulgence? *British Food Journal*.

Drugova, T., & Curtis, K. (2022, May). Why Can't the Supply Chain Keep Up with Organic Bakery Product Demand? Understanding Miller, Distributor, and Baker Organic Wheat Quality Perceptions and Needs. *International Food and Agribusiness Management Review*, 24(4), 601-617.

Wagner, K. M., Curtis, K., & Jewkes, M. (2022, December). The Impact of Free Senior Center Farmers' Markets During Covid-19. *Journal of the National Association of County Agriculture Agents*, 15(2).

Presentations:

Curtis, K. (Presenter & Author), Stock, M. (Author Only), Food Distribution Research Society Annual Meeting, "Growing a New Cut Flower Industry: Market Needs & Preferences," Pensacola, FL. (October 2022)

Drugova, T. (Presenter & Author), Curtis, K. (Author Only), Food Distribution Research Society Annual Meeting, "The Impact of Taste Beliefs on Consumer Perceptions of Organic Specialty Bakery Products," Pensacola, FL. (October 2022)

Curtis, K. (Presenter & Author), Agricultural and Applied Economics Association Annual Conference, "Models of Resiliency Among Smaller-scale and Family-owned Agricultural Enterprises,," Anaheim, CA. (August 2022)

Curtis, K., International Workshop on Agritourism, "Understanding and Enhancing Diversity, Equity, Access, and Inclusion in Agritourism: Innovative Research and Outreach in Entrepreneurship," University of Vermont, Burlington, VT. (August 2022)

Plan of Work:

Local foods marketing, farmers' markets and agritourism:

One journal article is under review and a proceedings paper will be published in 2023.

Webinars and presentations in this area will continue in 2023.

Organic Wheat Marketing Study:

Research and analysis for this project has been completed. Two journal articles will be submitted for review in early 2023. Two Extension fact sheets will be submitted for review in 2023 and two additional fact sheets drafted.

One journal article is currently being drafted and will be submitted for review in 2023.

Organic Strawberry Marketing Study:

The field and lab experiments will be conducted spring to fall 2023. Analysis will begin as soon as the experiments are completed. One Ph.D. dissertation, including three academic papers will result. Results will be presented at academic and industry conferences. Approx. 4-6 extension publications will be published.

Local Cut Flower Marketing Study:

One conference proceedings paper will be published in 2023. Additional outreach presentations based upon florist survey results will be given in 2023. If the grant applied for in 2022 is funded, new research will begin with additional academic and Extension outputs.

Molecular Mechanisms Regulating Skeletal Muscle Growth and Differentiation

Project Director

Kara Thornton-Kurth

Organization

Utah State University

Accession Number



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

- Characterize the molecular mechanisms controlling skeletal muscle tissue growth, development and composition.
- Characterize the signal transduction pathways that regulate skeletal muscle metabolism.
- Characterize mechanisms of protein synthesis and degradation in skeletal muscle.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The following items were accomplished relative to the goals of this project:

- Gained important insights into how mitochondria contribute to postmortem proteolysis and tenderization of meat.
- Described molecular mechanisms contributing to enhanced meat tenderness following ultrasonication.
- Identified potential protein biomarkers associated with meat tenderness through proteomic analysis.
- Gained a deeper understanding of how cattle of different breed types respond to anabolic implants.
- Learned more about the mechanism through which anabolic implants improve growth of skeletal muscle in beef cattle.
- Deepened our understanding of the relationship between trace minerals and the hormones found in anabolic implants and their relationship to skeletal muscle growth.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Skeletal muscle growth academicians, cell biology academicians

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Currently, no changes are being made to the outlined project.

Training and Professional Development:

A total of one PhD student and two different undergraduate students have helped to complete this research. Each of these students has been trained in different laboratory techniques that are related to this project and are pertinent to their research projects.

Dissemination:

The findings of this research have been presented annually at the NC1184 meeting as well as at national conference of the American Society for Animal Science and the Reciprocal Meats Conference. In addition, this data has also been presented at local department research seminars.

The research that has been completed in this project over the past year has resulted in three different manuscripts and three different conference presentations

Products:

Other Products:

Data and Research Materials Collected data regarding the role of the mitochondria and its relation to end-product quality

Data and Research Materials conducted proteomic studies in relation to beef tenderness

Data and Research Materials Completed an animal trial with cattle of different breed types receiving different anabolic implants

Data and Research Materials collected proteomic and transcriptomic data related to the effects of anabolic implants on skeletal muscle growth

Data and Research Materials Completed some cell culture studies analyzing how trace minerals affect skeletal muscle growth in primary bovine satellite cells

Plan of Work:

We will continue working on objectives 1 and 2

Arthropod management in Utah field crops

Project Director

Ricardo Ramirez

Organization

Utah State University

Accession Number

1022928



Arthropod management in Utah field crops

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The objectives are to: 1) conduct on-farm surveys to determine the composition of arthropods on field crops, 2) conduct greenhouse trials to compare susceptibility of varieties to arthropod herbivory, 3) evaluate the effect of insecticides on arthropod pests and beneficials, and 4) conduct outreach on field crops to provide resources enabling growers to implement IPM practices.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

A total of 15 corn fields distributed across three counties: Weber, Box Elder, and Cache counties in Utah were surveyed for mites at the edges of corn fields. Data were collected from three randomly placed 0.25 m² quadrats along a 20 m transect at the edge of corn fields. Weeds within the quadrat were identified to species, counted, and recorded. In addition, spider mites were counted to determine association with potential weed hosts. Some of the most common weeds included, Downy brome, quackgrass, kochia, scouring rush, green foxtail at more than 8 plants/0.25 sq m. The common weeds hosting the two-spotted spider mite were field bindweed, volunteer wheat, and common mallow. We also found bitter nightshade, prostrate knotweed, puncture vine, and barnyard grass as potential hosts of a monocot specialist, Banks grass mite. This was particularly surprising given that a grass specialist was found on broadleaf weeds. More research is needed to understand these findings.

In 2021, four cultivars, Trump, Stormy Daniels, BaOx, and Cherry, were evaluated to determine relative susceptibility to mites and the effect of mite herbivory on cannabinoid concentrations. These data were processed in 2022 and were combined with the earlier trial in 2020. We found that spider mite densities differed significantly among cultivars, with spider mites appearing to prefer Berry Blossom and Tokyo in 2020 and BaOx in 2021. In both years, Cherry and Trump showed relatively low mite density. However, neither total THC nor total CBD concentrations differed between the control and mite treatments in either the 2020 or 2021 trials ($p>0.05$). Furthermore, there was no significant correlation between mite density and THC or CBD concentration. When analyses were split among cultivars, to determine if any one cultivar differed in THC or CBD concentration between the control and mite treatments, no cultivars showed any difference in THC concentration between the control and mite treatments. Only one cultivar, Stormy Daniels, showed a significant difference in CBD concentration between the control and mite treatments, with CBD increasing in the presence of mites ($p<0.05$).

In 2022, we conducted a subsequent greenhouse trial to evaluate caterpillar development on four different hemp cultivars: Trump, Tokyo, Cherry, and BaOx. Ten plants per cultivar were planted in pots and grown for 2 months after which 10 beet armyworm (*Spodoptera exigua*) eggs were placed within a leaf cage on each plant. Plants were evaluated across 2-weeks to follow larval emergence, larval growth, and leaf consumption. Our initial results indicate that larval emergence from egg and survival was an average of 4.3 larvae after 8 days across all cultivars. There was no significant difference among cultivars. After 14 days post egg introduction, larval numbers averaged 1.8 larvae across all cultivars with no striking difference among the cultivars. At the end of the trial (14 days of herbivory), 7 leaves from each plant were collected and dried in preparation for cannabinoid testing. These samples have been submitted to a chemistry lab for evaluation and will be matched with caterpillar herbivory associated with each plant. We are currently evaluating area of leaf consumption to determine whether there are any differences in herbivory across cultivars and more closely evaluating larval development on each cultivar.

We continue on creating and fine-tuning survival curves for several insecticides used in the alfalfa system. Using bottle assays, survival curves for chlorpyrifos and lambda-cyhalothrin were most easily developed for both alfalfa weevil larvae and *Lygus* spp. Generally, higher concentrations of chlorpyrifos were needed to find diagnostic doses for lygus (LC50 = 18 ug/ml and LC90 = 162 ug/ml) compared to alfalfa weevil (LC50 = 8 ug/ml and LC90 = 34 ug/ml). For lambda-cyhalothrin, the LC50 for lygus and alfalfa weevil were similar, but higher concentrations were needed to achieve the LC90 for alfalfa weevil (LC50 = 9 ug/ml and LC90 = 107 ug/ml) compared to lygus (LC50 = 10 ug/ml and LC90 = 43 ug/ml). Alfalfa leafcutting bees were highly susceptible to both chlorpyrifos (LC50 = 2 ug/ml and LC90 = 4 ug/ml) and lambda-cyhalothrin (LC50 = 9 ug/ml and LC90 = 16 ug/ml).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

We have targeted our work on hemp, corn, and alfalfa pests and beneficials toward growers and pesticide applicators. One way to engage these groups is to also target our Extension faculty and Crop Advisors who can then deliver this information to growers in their respective counties and regions. Work from this project also targeted the scientific community.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report

Training and Professional Development:

Desiree Wickwar assisted in the early stages of the hemp project and completed the processing and analysis of the spider mite results and plant chemical responses. Desiree completed her MS and started a new position in the summer of 2022 with the University of Idaho as the Integrated Pest Management Program Manager. Rose Sepesy converted her MS program to a PhD program with a focus on alfalfa insect research with Dr. Ramirez as a co-advisor. Rose is developing her skills in arthropod and plant maintenance, experimental design, and data collection and organization. She is also becoming familiar with pesticide

knowledge and conducting pesticide exposure bottle assays. Moreover, Rose has presented her work at conferences since beginning her research and has developed her skills in scientific communication. Mercy Odemba began her PhD degree January 2020 with Dr. Ramirez, focusing her work on arthropod outbreaks in corn and the relationship between arthropods and weed hosts. Mercy has also developed her skills in arthropod and plant maintenance and has become familiar with experimental design and data collection. Finally, two undergraduate students have gained experience in experimental design and data collection as part of a hemp research project screening hemp cultivars for herbivore resistance.

Dissemination:

To deliver information to our target groups we developed presentations for trainings that highlighted pesticides associated with alfalfa and the connection of weed management for the suppression of arthropod pests of corn, and hemp trials associated with spider mites. Our Extension outreach efforts included alfalfa and corn presentations and a fact sheet and newsletter, and a hemp presentation at an annual conference of extension. In addition, we presented at the Entomological Society of America national conference in 2022. We provided ways to monitor and identify insect pests in each respective crop system and identified factors leading to pest issues.

Publications:

Periodicals:

Odemba, M., & Ramirez, R. (2022). The complicated relationship of weeds, arthropods, and crops. (winter ed., vol. 16). Utah Plant Pest Diagnostic Laboratory and USU Extension Publication.

Sepesy, R., Bernhardt, S., & Ramirez, R. (2022). Battling the resistance (of pesticides)- A growing issue in alfalfa? (winter ed., vol. 16). Utah Plant Pest Diagnostic Laboratory and USU Extension Publication.

Other

Vardiman, J., Schell, S., Wanner, K., Rod bell, E., Ramirez, R., & Bradshaw, J. (2022). Management of insecticide resistance in alfalfa weevil for the Intermountain West: Montana, Utah, and Wyoming. (MP-154 ed.). University of Wyoming Extension Publication.

Presentations:

Odemba, M. (Presenter & Author), Creech, J. E. (Author Only), Ransom, C. (Author Only), Yost, M. (Author Only), Ramirez, R. (Author Only), Entomological Society of America Annual Meeting, "Why can't we be friends: Weed host interactions with spider mites in Intermountain West corn production," Entomological Society of America, Vancouver, BC. (November 14, 2022)

Sepesy, R. (Presenter & Author), Bernhardt, S. (Author Only), Ramirez, R. (Author Only), Hageman, K. (Author Only), Pitts-Singer, T. (Author Only), Pacific Branch Entomological Society of America Annual Meeting, "Evaluating the toxicity of chlorpyrifos and lambda-cyhalothrin in alfalfa weevil, lygus, and alfalfa leafcutting bee," Entomological Society of America, Virtual. (April 10, 2022 - April 13, 2022)

Plan of Work:

For objective 1, we will continue to process samples. For objective 2, we plan to analyze hemp greenhouse trials to complete data for two years and begin developing a manuscript. For objective 3, we are continuing bottle assays. We will be completing analyses and begin developing manuscripts for each of the objectives.

Bilin Protection of Plants from Abiotic Stress

Project Director

J Takemoto

Organization

Utah State University

Accession Number

1023003



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

A) Produce mesobiliverdin IXalpha-enriched microalgal (MEM) extracts.

B) Demonstrate abiotic stress protection in plants by purified mesobiliverdin IXalpha (MBV) and MEM extracts.

C) Show that MBV and MEM extracts protect against abiotic stress by mechanisms that resemble those of biliverdin IXalpha (BV) generated by heme oxygenase I (HO-1).

Year 1: Produce MEM extracts with a range of MBV concentrations (5 to 100 microM). Begin cadmium abiotic stress protection experiments with soybeans.

Year 2: Continue cadmium abiotic stress protection experiments with soybeans. Begin boron abiotic stress protection experiments with *A. thaliana*.

Year 3: Continue abiotic stress experiments with *A. thaliana*.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

1) The role of heme oxygenase I (HO-1) in AggieGrow protection against abiotic stress was examined. Corn leaf discs were floated in 50 mM phosphate buffer (pH 7.4) with AggieGrow, microalgae extract or MBV each with and without Zn-protoporphyrin IX (ZnPPIX) for 1 to 4 days. ZnPPIX is an HO-1 inhibitor. Controls were addition of AggieGrow, microalgae extract or MBV and no ZnPPIX. ZnPPIX exposure in combination with AggieGrow or MBV resulted in higher HO-1 activities compared to microalgae extracts without ZnPPIX. These experimental results indicate a role for HO-1 in protection against abiotic nutrient stress by MBV.

2) Field studies were conducted to assess the effects of AggieGrow (10% MBV by weight) on corn germination, growth and root development under nutrient stress conditions. Bodacious RM Hybrid Sweet Corn seeds were purchased from a local seed company. The seeds were soaked in water overnight with and without AggieGrow solution (1 g per 100 mL water) before sowing in an outdoor garden plot (10 ft x 20 feet) in July 2022. Two 15 ft rows each of AggieGrow-treated and control (no AggieGrow treatment) seeds were sown. AggieGrow solution or water (control) were applied every 3 days for two weeks. No soil fertilizer was applied. Thereafter, AggieGrow solution was provided once every 10 days and plants were drip-irrigated without fertilizer application. Plants with intact roots were collected 80 days after sowing and root structures were analyzed. Results: AggieGrow treatment accelerated seed germination (by 3-5 days) and growth (plant heights ~30% average taller), and resulted in more root complexity (more secondary and tertiary roots) and lengths as compared to controls. These results indicate that AggieGrow protects and promotes growth of corn under abiotic nutrient stress conditions in the field.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

crop farmers
plant fertilizer markets
abiotic stress researchers

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Abiotic nutrient stress field studies with corn were added in 2022. Field studies were not initially proposed for this project. However, given the earlier progress and success with corn nutrient stress in this project in 2021, it was decided to pursue field studies with corn. Experiments on the role of heme oxygenase in responses to abiotic stress will be pursued in 2023 with *Arabidopsis thaliana* to gain more insight into the larger role of HO-1 protection against plant abiotic stress in general (i.e. not only nutrient stress in corn). Such studies were initially proposed for this project.

Training and Professional Development:

Undergraduate students received experience and training in preparative chemistry methods for production, extraction and analysis of heme-derived natural products.

Dissemination:

Results and data have been disseminated to an agricultural biotechnology company and a corn growers association under conditions specified in non-disclosure agreements and in cooperation with the Utah State University Technology Transfer office. Discussions with the company are currently underway.

Publications:

Refereed Journal Articles:

Liao, T.-S., Chen, C.-Y., Lin, C.-S., Chang, C. W. T., Takemoto, J. Y., & Lin, Y.-Y. Mesobiliverdin IX α -enriched microalgae feed additive eliminates reliance on antibiotic tylosin to promote intestinal health of weaning piglets. *Animal Bioscience*.

Wood, J., Takemoto, J. Y., & Sims, R. C. (2022). Rotating algae biofilm reactor for management and valorization of produced wastewater. *Frontiers in Energy Research*, 10, 774760.

Other Products:

Data and Research Material - Heme-derived bilin products are generated from this project. They have a broad range of applications that include agricultural crop and animal protection, food and drink products, therapeutics against chronic and acute inflammatory diseases, beneficial animal and pet feed, environmental remediation technologies, infectious diseases, and medical research technologies. Industry and academic partners collaborate with USU in research/development and marketing of these products. The Utah State University Technology Transfer Services oversees these collaborative arrangements. Intellectual property patents on the production and applications of these products have been issued or are pending.

Plan of Work:

A. thaliana seeds (Columbia wild-type and HO-1 mutant strain *hy1-100* (CS236)) will be sown on solid half-strength Murashige and Skoog medium with 0.05, 1, 2, 3, 4 mM or no boron and with or without AggieGrow, microalgae extract, or MBV (5–100 μ M) in 6-well microtiter plates. After cold exposure at 4°C for 2–4 days in the dark, the plates will be transferred into a growth chamber at 21–22°C under cool-white fluorescent light. Each day after the transfer, the plates will be examined for germination rates. Seeds germinating on plates will be scored, and the relative root lengths of 10-day-old seedlings will be measured. Root length is inversely proportional to degree of stress. For *A. thaliana* Columbia wild-type strain, boron-only treatments are expected to result in decreased germination rates and root lengths because of abiotic stress. Increased germination rates and root lengths with MBV and AggieGrow exposure will indicate protection against boron-induced abiotic stress. With *A. thaliana* HO-1 mutant strain *hy1-100* (CS236) strain plants, boron-only treatments are expected to result in decreased germination rates and root lengths that will be more pronounced than those of wild-type *A. thaliana* plants. This will indicate a role for HO-1 in protection against boron abiotic stress. For all experiments, data will be statistically analyzed using student t-tests to identify significance levels. Concentration dependencies will also be statistically analyzed using one-way ANOVA to identify effective dosages.



Optimizing inputs for forages and field crops in Utah

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Small grains: determine the effect of one-time compost applications and cover crops on dryland organic wheat yield and quality.
2. Oilseeds: determine the seeding rate necessary to establish optimal dormant-seeded safflower stands and further refine chemical options for weed control in dormant seeded safflower.
3. Corn: determine the effect of row spacing and seeding rate on grain corn hybrids.
4. Forages: determine the management practices to avoid glyphosate injury to glyphosate resistant alfalfa.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Small grains: determine the effect of one-time compost applications and cover crops on dryland organic wheat yield and quality

In 2022, graduate student Brad Davis continued work on this objective as part of his PhD dissertation. The field research experiments continued on a USU farm in Blue Creek, UT and on a producers farm in Snowville, UT and Monticello, UT. Data was collected on cover crop, weed growth, and wheat yield and yield components in 2022. Wheat yields at all locations appear to be responding positively to compost. Cover crops appear to consistently decrease wheat yield. Blue Creek was in the fallow phase in 2022, as well. Little to no yield difference has been noted in that location. Measurement of wheat quality in the laboratory is ongoing. Wheat was planted this fall for harvest in 2023.

Progress towards the successful completion of this objective will lead to the development of new management recommendations for organic dryland wheat growers that will increase soil fertility and health, soil moisture storage, and wheat yields in organic dryland wheat systems. Understanding differences in crop response to compost among sites will enable us to predict when it is economically viable to apply compost and when it is not.

Oilseeds: determine the seeding rate necessary to establish optimal dormant-seeded safflower stands and further refine chemical options for weed control in dormant seeded safflower

Graduate student Rodney Nelson continued his work on this project in 2022. Experiments in Kaysville, Blue Creek, Clarkston, and Millville, UT were harvested. Analysis of data collected in the field is ongoing. Seed quality analysis is also underway. Dormant trials for harvest in 2023 were planted in 2022. Mr. Nelson plans to complete his thesis and graduate in early 2023.

Progress towards the successful completion of this objective will lead to the development of new management recommendations for safflower growers that will increase safflower yields and improve the economic sustainability of dryland farms. Understanding differences in seeding rates will enable us to make recommendations that will produce viable crop stands for maximum yields. Furthermore, knowledge of herbicide options for weed control will give farmers options to prevent yield loss due to weed competition.

Corn: determine the effect of row spacing and seeding rate on grain corn hybrids

Work is scheduled to begin on this objective in 2023 with the recruitment of a new graduate student.

Forages: determine the management practices to avoid glyphosate injury to glyphosate resistant alfalfa.

Field work on this objective has finished, student Chet Loveland has graduated, and a manuscript is in preparation for publication in early 2023. Progress towards the successful completion of this objective has lead to the development of management strategies for glyphosate resistant alfalfa to avoid crop injury due to the interaction between freezing temperatures and alfalfa growth when treated with glyphosate.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences include Agricultural producers, Extension personnel, government agencies, agribusiness personnel, and other scientists.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None to report at this time.

Training and Professional Development:

In 2022, the project provided 6 graduate students (Megan Getz, Rodney Nelson, Brad Davis, Michael Greenland, Benson Israelsen, and Kyle Forsyth) with training in field plot establishment and maintenance, and data collection techniques. Ms. Getz received her PhD and Mr. Greenland his MS degree in 2022.

Dissemination:

To date, dissemination has consisted primarily of presentations at national and regional conferences, field days, and Extension meetings. During the reporting period and directly related to my AES project, graduate students and I made 14 presentations at national and regional conferences and published 6 manuscripts in refereed journals. Research from my AES project was also presented at 39 Extension meetings and field days in Utah and across the western US and in 31 field tours of my research plots with small groups of Extension personnel, industry representatives, and agricultural producers.

Products:

Publications:

Refereed Journal Articles:

Atoloye, I. I., Jacobson, A., Creech, J. E., & Reeve, J. (2022, July). Soil organic carbon pools and soil quality indicators 3 and 24 years after a tone-time compost application in organic dryland wheat systems. *Soil and Tillage Research*, 224.

Greenland, M., Waldron, B., Isom, S., Fonnesbeck, S., Peel, M., Rood, K., Thornton-Kurth, K., Miller, R. L., Hadfield, J., Henderson, B., & Creech, J. E. (in press). Dry-matter intake and feed efficiency of heifers from four dairy breed-types grazing organic grass and grass-birdsfoot trefoil mixed pastures. *To appear in Journal of Dairy Science*.

Holt, J., Yost, M., Creech, J. E., Allen, L., McAvoy, D., & Winward, D. (2022). Biochar had minor impacts on yield, quality, and water availability of alfalfa, corn, and wheat. *Agronomy Journal*, 114, 1717-1730.

Roberts, C., Yost, M., Ransom, C., & Creech, J. E. (2022). Oat companion seeding rate, herbicide, and irrigation effects on alfalfa establishment. *Agronomy Journal*.

Sullivan, T., Yost, M., Boren, D., Creech, J. E., Kitchen, B. M., Violett, R., & Barker, B. Irrigation Technology, Irrigation Rate, and Drought-Tolerant Genetics Impacts on Silage Corn Production. *Agronomy Journal*.

Zesiger, C., Hadfield, J., Pace, M., Yost, M., Creech, J. E., & Palmer, M. D. (2022, June). EVALUATION OF COVER CROP PRODUCTIVITY FOR INTEGRATED CROP-LIVESTOCK SYSTEMS IN THE INTERMOUNTAIN WEST. *Journal of NACAA*, 15(1).

Other:

Creech, J. E., Reeve, J., Yost, M., Jacobson, A., Davis, B., & Atoloye, I. (2022). Compost Carryover and Cover Crops in Dryland Organic Wheat in Utah.

Plan of Work:

Continue to collect data through the 2023 growing season. Analyze data from previous years in preparation for publication and thesis defense for three MS students in 2023. Host field days and field tours of research and demonstration plots. Speak at conferences and winter crop school meetings on the research conducted as part of this AES project.

Soil Fertility and Salinity Management in Utah Agricultural and Horticultural Production

Project Director

G Cardon

Organization

Utah State University

Accession Number

1023323



Soil Fertility and Salinity Management in Utah Agricultural and Horticultural Production

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Soil Fertility Management

The studies undertaken in this area of focus will be designed to accomplish the primary objective of determining, and then addressing through need-driven research, the gaps in Utah-specific soil fertility interpretive and management information for the economically important agronomic (hay and grain) and horticultural (tree fruits) crops grown in the state.

Soil Salinity Management

The primary objective of the efforts in this area of focus is to quantify the extent and severity of soil and water salinity conditions contributing to agronomic and horticultural cropping system performance, the understanding of which is critical to the sustainability of agriculture across the state, and evaluate crops for productive use in saline soil environments.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Research on the evaluation of optimal combinations of 4R fertility management practices in multiple cropping systems (corn, wheat, potato and tart cherry production) in the Intermountain West, is ongoing. The research objectives are to better correlate the relationships between soil health management techniques and crop management. This lack of understanding how in-field management influences soil health is a significant gap in efforts of the USDA to monitor and leverage improvements in soil health locally and nationally. The intermediate results were reported on in workshops presented to irrigators and agronomic consultants in the Intermountain West via online crop schools and field days and published in Extension Fact Sheets, peer-reviewed journal articles and presented in several scientific conferences as noted in the list of outputs for this project. Field work was begun this last year under the large grant (\$1.9 million) through the USDA Specialty Crop Program, that was noted last year. The project funds research into large-scale variable-rate fertility management in tart cherry production in Utah, Idaho and Michigan. Field trials on six grower-cooperator tart cherry blocks were deployed on

which detailed maps of soil conditions, tree canopy structure, and disease and pest incidence, have been developed. In addition, ET and multi-spectral satellite imagery of the blocks has also been obtained, to be used in guiding variable-rate management zone development and monitoring changes influenced by differential management in the study orchards. One of the important spatial variables—tree-level fruit yield—is not easily obtained from industrial harvest practices. We are also developing an on-the-go sensor system to obtain this data, which, if successful, will be a particularly novel and useful technological contribution to both this area of research and the tart cherry industry.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Agricultural and horticultural producers, rural and urban homeowners/gardeners, agricultural and horticultural industry personnel (fertilizer providers, landscape professionals, nurseries, consultants, etc.), and government agency personnel (federal, state and local) that deal with soil, plant and water issues.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None experienced or foreseen besides ensuring compliance with COVID-related protocols for shared space and travel of project personnel and cooperators.

Training and Professional Development:

One MS graduate assistant involved in the research on 4R fertility management is in the process of writing their thesis, with an expectation of graduation by May 2023. Three additional graduate assistants (two MS and one PhD) have begun work on various projects within the Specialty Crop Program study. These students are in the early stages of course work and initial field research on the project.

Dissemination:

Information was published in numerous ways to provide both academic and educational summary of the research. Graduate research formed the foundation of the information published in scientific presentations at regional and international conferences, and in peer-reviewed research journal articles and Extension Fact Sheets.

Products:

Presentations:

Cardon, G. (Presenter & Author), Department Seminar, "Impact of Salinity and Alkaline pH on Nutrient Management in Calcareous Soils of the Western U.S," University of WI, Soil Science Dept., Madison WI. (February 23, 2022)

Cardon, G. (Presenter & Author), Department Seminar, "Improving Tart Cherry Productivity and Profitability Through Variable-Rate Precision Management: A New Multi-State, Multi-Discipline Project," University of Minnesota, Soil, Water and Climate Dept., St. Paul MN. (February 9, 2022)

Plan of Work:

Efforts reported on last year to utilize recent soil fertility management research to revise the recommendations for small grains following alfalfa are still in review and we plan to implement them in late 2023. Research on the optimization of 4R soil fertility management practices in tart cherry production will continue for the 4th and final year of the project. Results from the stacked 4R study will continue to be used to inform research efforts on the newer USDA Specialty Crop Program, multi-state, variable-rate fertility management research study in tart cherries begun this last year.

Project Director

Jeanette Norton

Organization

Utah State University

Accession Number

1022927



Understanding agricultural soil microbiomes for improved nitrogen management and soil health

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1) Nitrification ecology and genomics in Utah agricultural soils

Continue characterization of nitrifying microbes in Utah agroecosystems. Determine the role of comammox Nitrospira in Utah agricultural soils under different management. Sequence genomes of ammonia oxidizing microbes (AOM) isolated from soils in Utah. Examine controls on the production of nitrous oxide from nitrifying organisms. Identify ability of cropping systems that promote biological nitrification inhibition to decrease the rate or extent of nitrification.

2) Mineralization enzymes under contrasting management

Examine response of mineralization enzymes and genes encoding mineralization functions to agricultural management. Identify microbiome compositions that promote N availability for crops. Work on timing of N availability for divergent N sources. Work towards management of the microbiome to optimize N cycle processes.

3) Characterize bioavailable nitrogen pools

Characterize organic nitrogen pools in soils and relate to N available for plant assimilation (PAN) under contrasting management.

4) Nitrogen Cycling in Agricultural Systems

Work towards improving prediction of available N in diverse management systems. Improve existing soil health indicators for N cycling. Follow effects of management on nitrogen use efficiency.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Our focus was to improve understanding of the role of soil biological processes in controlling plant available nitrogen and their relationships with soil health and system resilience. Results of this research will make cover crop integration more successful in corn-based cropping systems and avoid excess N fertilizer application when cover crops are implemented. - The emerging relationships between soil health indicators and the economic optimum N rate will help to advance soil testing to improve the precision of N fertilizer management. - Understanding how management practices such as irrigation method and cover crop use affect N₂O emissions will inform strategies to reduce the carbon footprint of agriculture.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

students, academics, scientists international

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to

communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Writing publications has taken significant editing and there has been equipment failures causing delays in sample analysis.

Training and Professional Development:

training for role of graduate program coordination

Dissemination:

academic, peer review publications, international meetings in Ireland (Norton) and Cambodia (P. Miller graduate student), SSSA meetings, presentations to USU audiences

Products:

Publications:

Refereed Journal Articles:

Fremin, B. J., Bhatt, A. S., Kyrpides, N. C., & Norton, J. M. Thousands of small, novel genes predicted in global phage genomes. *Cell Reports*, 39, 110984.

Habteselassie, M. Y., Woodruff, L., Norton, J. M., Ouyang, Y., & Sintim, H. (2022, September 24). Changes in Microbial Communities in Soil Treated with Organic or Conventional N Sources. *Journal of Environmental Quality/ Wiley*.

Ouyang, Y., Reeve, J. R., & Norton, J. M. (2022, August 02). The quality of organic amendments affects soil microbiome and nitrogen-cycling bacteria in an organic farming system. *Frontiers of Soil Science, Frontiers*, 2, Front. Soil Sci. 2:869136.

Ouyang, Y., Norton, J. M., Cole, J. R., Evans, S. E., Friesen, M., Tiedje, J. M., & Tiemann, L. K. Genomic and metagenomic analyses of genes involved in soil nitrogen mineralization. *Soil Biology and Biochemistry*.

Presentations:

Norton, J. M., JGI Genomics of Energy and the Environment, "Genomes, Metagenomic Assembled Genomes (MAGs) and Metagenomic Enrichments for Nitrifying Communities in Soil," DOE, Berkeley California. (August 15, 2022)

Plan of Work:

Doctoral student Phearen Miller is finishing data collection, statistical analysis and research reports for publication. she advanced to candidacy in 2022. There will be several publications submitted in 2023 from her dissertation.

Improving Forage and Bioenergy Crops for Better Adaptation, Resilience, and Flexibility

Project Director

J. Creech

Organization

Utah State University

Accession Number

1021751



NE1710: Improving Forage and Bioenergy Crops for Better Adaptation, Resilience, and Flexibility

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Developing broadly adapted, climate resilient forages for sustainable cropping systems.
2. Understanding genotype by environment interactions across multiple forage species

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

On this project, I work closely with the plant breeders in the USDA-ARS Forage and Range Research Laboratory in Logan, UT. As an Agronomist, my role is serve as a bridge between the forage breeders and agricultural producers in evaluating new germplasm in different environments and developing management practices to improve forage yield and nutritive value.

PhD student Megan Getz graduated in 2022 with an emphasis in identifying the molecular markers and expression of candidate genes for flowering time to select late heading orchardgrass. Orchardgrass with this characteristic will be more desirable by improving the yield and nutritive value in grass-alfalfa mixtures. MS student Carson Roberts graduated in 2021 with a thesis project designed to assess companion seeding oats as an aid to alfalfa establishment. MS student Chet Loveland completed his thesis in 2020 and evaluated management practices to avoid injury from freezing temperatures to glyphosate-resistant alfalfa. MS student Michael Greenland graduated in 2022 and assessed the performance of dairy cattle breeds on various pasture grasses (tall fescue, orchardgrass, meadow brome, and perennial ryegrass) grown in mixtures with birdsfoot trefoil. Multi-year experiments on reduced lignin alfalfa were completed.

New variety trials were established in 2020 for alfalfa and timothy. In alfalfa, a 43 entry variety trial was established at a saline location near Castle Dale, UT. Two additional alfalfa variety trials were established at the USU Greenville Research Farm near North Logan, UT. A variety trial for timothy was also established at the Greenville Farm.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences include Agricultural producers, Extension personnel, government agencies, agribusiness personnel, and other scientists.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None to report at this time.

Training and Professional Development:

This project provided training in forage research for 6 graduate and 8 undergraduate students in over the past 3 years.

Dissemination:

To date, dissemination has consisted primarily of presentations at national and regional conferences, field days, and Extension meetings. During the 2022 reporting period, graduate students and I made 14 presentations at national and regional conferences and published 6 manuscripts in refereed journals. Research from my AES project was also presented at 39 Extension meetings and field days in Utah and across the western US and in 31 field tours of my research plots with small groups of Extension personnel, industry representatives, and agricultural producers.

Publications:

Refereed Journal Articles:

Atoloye, I. I., Jacobson, A., Creech, J. E., & Reeve, J. (2022, July). Soil organic carbon pools and soil quality indicators 3 and 24 years after a tone-time compost application in organic dryland wheat systems. *Soil and Tillage Research*, 224.

Greenland, M., Waldron, B., Isom, S., Fonnesebeck, S., Peel, M., Rood, K., Thornton-Kurth, K., Miller, R. L., Hadfield, J., Henderson, B., & Creech, J. E. (in press). Dry-matter intake and feed efficiency of heifers from four dairy breed-types grazing organic grass and grass-birdsfoot trefoil mixed pastures. *To appear in Journal of Dairy Science*.

Holt, J., Yost, M., Creech, J. E., Allen, L., McAvoy, D., & Winward, D. (2022). Biochar had minor impacts on yield, quality, and water availability of alfalfa, corn, and wheat. *Agronomy Journal*, 114, 1717-1730.

Roberts, C., Yost, M., Ransom, C., & Creech, J. E. (2022). Oat companion seeding rate, herbicide, and irrigation effects on alfalfa establishment. *Agronomy Journal*.

Sullivan, T., Yost, M., Boren, D., Creech, J. E., Kitchen, B. M., Violett, R., & Barker, B. Irrigation Technology, Irrigation Rate, and Drought-Tolerant Genetics Impacts on Silage Corn Production. *Agronomy Journal*.

Zesiger, C., Hadfield, J., Pace, M., Yost, M., Creech, J. E., & Palmer, M. D. (2022, June). EVALUATION OF COVER CROP PRODUCTIVITY FOR INTEGRATED CROP-LIVESTOCK SYSTEMS IN THE INTERMOUNTAIN WEST. *Journal of NACAA*, 15(1).

Other:

Creech, J. E., Reeve, J., Yost, M., Jacobson, A., Davis, B., & Atoloye, I. (2022). Compost Carryover and Cover Crops in Dryland Organic Wheat in Utah.

Plan of Work:

Continue to collect data through the 2023 growing season. Analyze data from previous years in preparation for publication and thesis defense for three MS students in 2023. Host field days and field tours of research and demonstration plots. Speak at conferences and winter crop school meetings on the research conducted as part of this AES project.

Management and Environmental Factors Affecting Nitrogen Cycling and Use Efficiency in Forage-Based Livestock Production

Systems

Project Director

Rhonda Miller

Organization

Utah State University

Accession Number

1021515



NC1182: Management and Environmental Factors Affecting Nitrogen Cycling and Use Efficiency in Forage-Based Livestock Production Systems

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

NC1182 Objective 1. Quantify environmental and economic effects of forage- and pasture-based management strategies and climate change on N-use efficiency by ruminant animals, N cycling in herbage and soils, aquatic N losses, and greenhouse gas (GHG) and other pollutant emissions from grassland agro-ecosystems.

Specific Objective (iii): Determine N pool and cycling (soil, plant, atmosphere, and water), N-use efficiency and biological activity, and economic responses to management strategies in forage-based ruminant production systems with or without forage legumes across variable soil environments and climatic conditions.

NC1182 Objective 2. Assess the efficacy of secondary plant metabolites in legume species for increasing N retention and improving N-cycling in forage-livestock systems.

Specific objective (i): Evaluate effects of legumes containing tannins or other secondary plant metabolites on N partitioning in fecal and urine excretions.

NC1182 Objective 4. Disseminate research results through coordinated extension/education activities, including extension publications, university course material, and national, regional and state conferences on legume establishment, interseeding and management of grass-legume mixtures, and N cycling and use efficiency.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Plots were previously planted to four grasses: 1) tall fescue (TF) [*Festuca arundinacea* Schreb.]; 2) meadow brome (MB) [*Bromus biebersteinii*]; 3) orchard grass (OG) [*Dactylis glomerata*]; and 4) a high carbohydrate perennial ryegrass (PR) [*Lolium perenne*] as monocultures and as grass legume mixtures with birdsfoot trefoil (BFT) [*Lotus corniculatus*]. Fertilization scheme has been modified to observe any changes in nutrient leaching. Soil samples prior to fertilization were collected. Leachate samples were collected and are currently being analyzed for NO₃.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Other researchers examining nutrient cycling and environmental impacts in agricultural systems, ag professionals including NRCS, Extension agents, etc. and producers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None.

Training and Professional Development:

Attended the Waste-to-Worth conference in Maumee Bay, Ohio.

Dissemination:

Presented preliminary results of nutrient cycling in grass monoculture vs grass-legume mixture at the Waste-to-Worth conference, and the Utah Grazing Institute.

Plan of Work:

Continue with leachate sample collection and analysis.

Closing Out (end date 06/12/2024)

Sustainable microbial biocontrol of plant pathogens

Project Director

Robert Schaeffer

Organization



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overarching goal of this project is to identify a sustainable means of biocontrol for fire blight. More specifically, the following objectives will be addressed. First, diverse microbial taxa will be screened for their effectiveness at limiting *Erwinia amylovora*. Second, isolates tested will be screened metabolically to determine how resource use and other competition related traits inform patterns identified in Objective 1. Third, floral microbiomes of pome fruits will be surveyed to identify consortia design. Fourth, trials will be performed to determine their effectiveness both in the lab and field. Finally, the influence of consortia on vectors of biocontrol strains and *Erwinia* alike will also be tested.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Pear disease management – A significant research aim in the Schaeffer lab is centered on identification of sustainable strategies for disease control in pear. Pear is threatened by a number of bacterial and fungal pathogens, pre- and post-harvest. Of primary concern is *Erwinia amylovora*, the causal agent of fire blight, which also afflicts apple and other Rosaceous hosts. Current control measures for this bacterial pathogen, namely application of antibiotics, is not sustainable and alternative approaches are needed. To address this need, our research group has been conducting the following, complementary studies.

First, prior to joining USU, Schaeffer collected flowers samples from pear orchards in the Wenatchee region of central Washington. These samples were collected from orchards that varied in their IPM scheme (conventional, organic, and bio-based), as well as context (e.g., surrounding landscape cover). Since arriving to USU, these samples have been sequenced, and over the past year analyzed to investigate links between local orchard management practices, landscape cover, climate, and flower microbiome structure. Briefly, we found that bacteria and fungi respond differently to IPM schemes. Organic orchards had higher fungal and lower bacterial diversity in flowers than conventional or bio-based IPM orchards. Moreover, geographic distance among orchards was a poor predictor of alpha diversity, but patterns of bacterial and fungal diversity were affected by IPM scheme, surrounding land cover, and climatic factors. IPM scheme best predicted the distribution of several bacterial and fungal genera important for disease and disease suppression, with organic and bio-based IPM best explaining the distribution of bacterial and fungal genera respectively. Finally, IPM scheme was a primary factor influencing bacterial community similarity across sites, as well fruit orchard cultivation in the surrounding landscape. Geographic distance, climatic factors, management, and the amount of forest or pear produced in the surrounding landscape influenced fungal community turnover across sites. Taken together, these analyses reveal local- and landscape-level drivers of floral microbiome structure, providing insights that can potentially inform microbiome management and links to host health and yield quality. A manuscript stemming from these findings was published in 2021 in the journal *Applied and Environmental Microbiology*.

Second, microbes represent a promising alternative to synthetic chemicals for disease control. Currently, two microbiological products are used by pear and apple growers for management of fire blight. Active ingredients in these two products include *Bacillus subtilis* (bacterium) and *Aureobasidium pullulans* (yeast). Both have shown promise for fire blight control, but effectiveness can be variable, with the latter also on occasion causing russetting of fresh fruits. Alternative species, as well as species mixtures, may provide better control, without side effects that can affect the marketability of fresh fruit. Using diverse bacteria and fungi collected from agricultural and wild flower hosts, we've screened 50+ species for their potential in suppressing *Erwinia in-vitro* across different nectar environments, as well as *in-vivo*. Beyond measures of growth suppression, we are also analyzing effects of each antagonist species on nectar traits, including pH and sugar and amino acid content. These three nectar traits can play an important role in structuring microbe-microbe interactions in the hypanthium, and ultimately *Erwinia* success, as this is the primary site for infection. We are currently finishing nectar chemistry work and data analyses, with a manuscript planned for submission this upcoming spring (March 2023). This work is being led by a Masters student, Christopher McDaniel.

Third, while microbes represent a promising alternative to chemicals for disease control, there are still many unknowns

regarding the contribution of the floral microbiome to host resistance. PhD student Emily Burgess and I reviewed research concerning floral microbiome assembly and function in agroecosystems, including advances in microbial biocontrol of pathogens, in a recent perspective for the *Journal of Agricultural and Food Chemistry*. Future directions on research avenues are also included in this peer-reviewed manuscript. This article was published this fall.

Finally, our group was recently funded to explore related questions concerning microbial biocontrol of grey mold and powdery mildew in high tunnel strawberry production systems (Western SARE SW21-923). This work is in collaboration with Drs. Jennifer Reeve (lead PI), Brent Black, and Kynda Curtis at USU. A subset of microbial biocontrol agents explored for use in *Erwinia* control have recently been screened for their effectiveness in limiting grey mold, and how efficacy might vary with cultivar background. This work was led by PhD student Emily Burgess and undergraduate Emma Landenberger (Univ. of Vermont).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Target audiences of relevance during this reporting period include members of the academic research community, extension agents, and growers.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Pear disease management - *In-vitro/in-vivo* screening of prospective microbial antagonists of *Erwinia*, as well as dissection of the chemical mechanisms involved, was planned to be completed in spring 2022. Unfortunately, the High Performance Liquid Chromatograph (HPLC) instrument planned for use for sugar/amino acid analysis was down. We have been working to bring it back online this fall, and will continue these analyses into the winter, wrapping that project and manuscript submission.

Training and Professional Development:

A training and professional development opportunity was provided to one undergraduate student. Emma Landenberger, an undergraduate from the University of Vermont, joined our lab this past summer through the NSF Plant Health STEM program at USU. During her internship in the lab, Emma contributed to leaf disc assays that screened for the effectiveness of microbial biocontrol agents against grey mold in strawberry. She will be a co-author on a future manuscript.

Graduate students have also gained skills in integrated pest management, use of microbial biocontrol agents for disease control, as well as wet-lab, microbiology skills through participation in this research.

Dissemination:

Pear disease management – A manuscript on the pear flower microbiome has been published in the journal *Applied and Environmental Microbiology* (led by PI Schaeffer, published in 2021). A second manuscript evaluating the effectiveness of different microbial isolates on fire blight incidence, as well as mechanisms involved, is in preparation and will be submitted by March 2023 for publication. Furthermore, a graduate student and myself have published an invited perspective in the *Journal of Agricultural and Food Chemistry* on sustainable management of the floral microbiome. Finally, PI Schaeffer has been invited to speak on our research concerning the pear floral microbiome at the Washington State University Tree Fruit Research and Extension Center's Tree Fruit Days event in January 2023.

Strawberry disease management - A project meeting was held this December with grower-cooperators and other local stakeholders regarding progress to date. Results on our screening of microbial biocontrol of grey mold were shared with the group during this meeting. We also anticipate sharing some of these findings at the Utah Urban and Small Farms Conference in February 2023.

Products:

Other Products:

Data and Research Material - Pearflower microbiome structure and diversity

Data and Research Material - Screening of a diverse panel of bacteria and fungi for *Erwinia amylovora* suppression potential

Data and Research Material - Screening strawberry cultivars for resistance to grey mold, as well as their response when treated with a microbial control agent.

Plan of Work:

Pear disease management – We will continue to explore assays that assess the effectiveness of microbial consortia in suppressing *Erwinia*. We are also exploring potential pollination assays in spring 2023, to measure how addition of microbes to flowers may affect pollinator attraction, fruit yield and quality.

Strawberry disease management – We will continue to perform assays that assess the effectiveness of microbial biocontrol agents in suppressing grey mold and powdery mildew. Their effectiveness will be evaluated across different strawberry genotypes, as well as individual plants grown on and off compost to determine if there is synergism between the two in conferring greater host resistance. Finally, we have constructed an additional high tunnel at the USU student organic farm for experimental use; namely, screening the interaction between pollination, microbial biocontrol, and compost addition on strawberry resistance, yield, and fruit quality. This work is being led by PhD student Emily Burgess. Resources provided by this UAES award will complement those from Western SARE in supporting this work on sustainable microbial biocontrol of plant pathogens.

Closing Out (end date 06/12/2024)

Measurements and Models of Evapotranspiration of Irrigated Vineyards in California and Forage Crops in the Upper Colorado River Basin

Project Director

Lawrence Hipps

Organization

Utah State University

Accession Number

1020205



Measurements and Models of Evapotranspiration of Irrigated Vineyards in California and Forage Crops in the Upper Colorado River Basin

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The general goal is to address measurements and models of evapotranspiration (ET) for irrigated agriculture, and further development of methodology to improve precision of irrigation and quantify water use by key crops of the Utah and the Intermountain Region and several high value irrigated crops in California. Also, to develop methodology to simulate how warming summer temperatures will increase the demand for irrigation. The ET and the processes which control its value will be studied in two distinctly different agricultural regions of the western US, with very different climates, crops, and agroecosystems.

One case involves irrigated forage lands in the upper Colorado River Basin of Utah, Wyoming, Colorado and New Mexico. An existing project by the PI to monitor ET of these lands is already funded by the Bureau of Reclamation.

The other case deals with irrigated vineyards for wine production in California, where spatial distribution of ET is a critical need for optimizing water resources and product quality. The PI is already part of a current study of using remote sensing information to assess ET of vineyards, funded by NASA, USDA and Gallo Vineyards.

Specific objectives include:

Document the turbulence exchanges, microclimate and ET of irrigated vineyards. Use the findings to improve the remote sensing models of vineyard ET.

Use ET measurements of sites in the Upper Colorado Basin region to test and validate several ET models.

Develop a diagnostic model to simulate the changes on ET of irrigated lands in these cases with increases in summer temperatures that are already observed and predicted to increase. Also, use this approach to fill in gaps of ET data for both remote sensing models and validation measurements.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Activities focused several externally funded studies on quantifying the water use by irrigated crops including: evapotranspiration (ET) and microclimate in irrigated vineyards and Almonds; and Bureau of Reclamation (BOR) project to measure the ET of irrigated lands at four sites in the Upper Colorado River Basin; a Colorado-based study on effects of irrigation reductions on ET sometimes called demand management; and the ET of irrigated turfgrass at a golf course, and use of remote sensing-based models.

The NASA project of vineyard ET has been linked to a new project funded by the California Almond Board to examine the ET of irrigated Almonds and the role of advected heat from dry upwind surroundings. Eddy covariance measurements of surface energy balance were made both at a dry upwind location and above an irrigated almond orchard near Davis, CA. An instrumented drone was also flown to measure vertical profiles to a height of 200 m of temperature and humidity at both an upwind site over dry lands, and a site in the middle of the almond orchard, where eddy covariance measurements of ET were made. The profiles are analyzed to determine the amount of heat extracted from the layer of dry air from the upwind surroundings as it passed over the irrigated orchard. This is a measure of the importance of advection on the water use or ET of the orchard.

Microclimate measurements were made at high frequency (20 Hz) within the almond orchard canopy at several locations including between the rows and under the crown of the trees. These included the air temperature and three dimensions of turbulence with a sonic anemometer, and the water vapor density with an open path gas analyzer. These measurements were made completely synchronously with the same ones on the tower above the canopy. By combining these sets of data, one can document the dynamic nature of the microclimate in the orchard, how it is connected to the air above the canopy, and its role in affecting the ET of the orchard. It is hypothesized that as found in earlier studies for vineyards, the typical time average of temperature and humidity in the canopy, does not represent adequately the reality of alternating moist and drier air inside the canopy in response to periodic turbulence events.

The BOR funded study of the ET of irrigated crops at four locations in the Upper Colorado River Basin (one in each of the states of Utah, Colorado, Wyoming, and New Mexico) continued. The daily and seasonal ET values at each site, are used by the BOR to test multiple ET models. Models have shown variability in their ability to simulate the ET. This demonstrates the need for long term measurements to provide continuous validation points for the models.

Another season of ET measurements was made for the voluntary irrigation reduction study funded by the State of Colorado and Trout Unlimited. The ET estimates are supplied to the entire project to study the effects of demand management irrigation on water use in that study region.

The long-term project funded by PacifiCorp was continued that uses eddy covariance estimates of ET in three agricultural fields for scheduling irrigation with saline wastewater from a power plant. These results are integrated with soil moisture and precipitation to determine irrigation applications to ensure that saline water does not reach the groundwater.

Finally, more ET and energy balance measurements were made over a golf course in northern Utah. Periodic remote sensing data was acquired from multiple satellites and a USU instrumented UAV. The graduate student successfully developed methodology to estimate the leaf area index at many locations on the golf course. The USDA two-source ET model was successfully run to yield spatial estimates of ET. The model results are being validated with the eddy covariance measurements of ET. These data will be used to test the application of a remote sensing model for ET.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Other scientists both nationally and internationally. Federal and state water agencies.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No significant changes have been made.

Training and Professional Development:

A was conducted workshop with university, federal scientists and scientists with private companies, that covered an agreement of technical approaches and how we use our findings to inform the sponsors and interested users.

Dissemination:

Key results were delivered directly to the Bureau of Reclamation, NASA, California Almond Board the Colorado Basin Round Table and Trout Unlimited. In the case of the vineyard research, results were also shared with the private corporation (Gallo Inc.) that is a research partner in the NASA funded grant. The findings for the golf course ET and weather data were shared with the local golf course and the US Golf Association.

Publications:

Refereed Journal Articles:

van Opstal, J. D., Neale, C. M.U., & Hipps, L. E. (2022). Evaluating the adaptability of an irrigation district to seasonal water availability using a decade of remotely sensed evapotranspiration estimates. *Agricultural Water Management*, 261.

Plan of Work:

The research into the ET and microclimate of irrigated almonds will continue with several intensive field studies in the summer of 2023. Various advanced time series analyses will be conducted to document how certain scales of turbulence exchange of air above and within the canopy, govern the dynamic nature of both the microclimate in the orchard and the actual ET. In addition, the vertical turbulence flux of saturation deficit will be calculated above the canopy by the data from the eddy covariance system. This can be used to estimate the amount of the ET that is caused by the advection of warm, dry air from the hot and dry upwind lands.

The four towers funded by Bureau of Reclamation (BOR) will continue to be operated. The location in Utah near Vernal may be moved, since Utah State University has leased the land for other purposes. This project is now funded through 2026.

Monitoring the ET of the farms irrigated with wastewater by PacifiCorp will continue as in past years. Some changes will be made in which sites will be monitored and for what portion of the year.

The graduate student who works under the joint direction of Dr. Lawrence Hipps and Dr. Alfonso Torres, will continue her research on ET of turfgrass. She will combine the remote sensing data, eddy covariance estimates of ET and the two-source ET model to simulate the spatial variation of ET over the irrigated golf course. She will also do some analyses to examine how the ET values are affected by changes in weather and climate.

The project related to demand management irrigation in Colorado will be officially extended for two more years. We will continue to run the eddy covariance station, analyze the data, and provide the daily, monthly and seasonal ET values to the entire interdisciplinary group.

Closing Out (end date 06/12/2024)

Identification, characterization & utilization of microbes from the rhizosphere microbiome of Native plants in Utah to develop more resilient crops for salt & drought stress.

Project Director

Amita Kaundal

Organization

Utah State University

Accession Number

1019972

★ Identification, characterization and utilization of microbes from the rhizosphere microbiome of Native plants in Utah to develop more resilient crops for salt and drought stress

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Plants are sessile organisms bound to their place of origin. They cannot move to protect themselves from harsh environmental conditions. Climate change increases the incidences of extreme and harsh environments (Allen et al. 2010). The climate change refers to the rising of global temperature, elevation of carbon dioxide in the environment, change in precipitation etc. All these changes increase the incidence of drought, soil salinity, flooding, weeds and pest and disease susceptibility, which directly impacts the growth and development of crops and agriculture as a whole (FAO 2009). By 2100, the global mean surface temperature is expected to rise between 1.8 C - 4 C. These projected changes are expected to impact the growth and production of crops (de Gorter, Drabik, and Just 2013). It is a challenge to mitigate the effects of climate change and at the same time need to adapt to its consequences (FAO 2009). The other factor impacting negatively the agriculture and food production is increase in world population. The world population increased from 4.4 billion to 6.1 billion from 1980-2000. After 2000, the world population is increasing by the rate of 2% each year and reached to 7.5 billion in 2014. By 2050, it is estimated to reach 9 billion and the food demand is expected to increase 70-85% (FAO 2017, 2015; Ray et al. 2013; The World Bank, Population 2016). Various studies have shown that each degree Celsius increase in temperature could lead to 5% reduction of yield (Lobell, Schlenker, and Costa-Roberts 2011). Thus, feeding the increase in population under climate change is a challenge. This challenge demands to create more resilient crops to adverse conditions and feed the growing population.

Plants have developed various mechanisms to defend themselves to the extreme conditions in which they are native, or they are exposed. One way to develop more resilient crops is the dissection of these mechanisms and exploit them to develop genetically modified crops. Besides the genetic mechanism, plants have a rhizosphere microbiome that helps them to establish and survive in their habitat. The soil directly under the influence of plant's root is known as rhizosphere. This rhizosphere is rich habitat of various microbes which directly or indirectly influence the growth and development of plants above ground. Many plant growth promoting bacteria (PGPB) have been characterized and few of them are used as successful biofertilizers. The Intermountain West (IW) region in US is rich in drought tolerant native plants that are recommended to use in low water landscaping. These plants have not been explored for their rhizosphere microbiome. Investigation of the rhizosphere microbiome of these plants can lead to open new avenues such as their use in the development of more resilient agriculture under various adverse conditions and enhance the knowledge about the potential of these plants and their microbiome to mitigate the effects of climate change.

Objectives:

1. Comparative study of microbiome from bulk soil, rhizosphere and endophytes in native plants *Cercocarpus ledifolius* (curl leaf mountain mahogany), *Shepherdia rotundifolia* (roundleaf buffaloberry) *Sherferdia argentea* (silver buffaloberry), *Sphaeralcea globemallow*, *Ceanothus velutinus* (snowbrush) from two different locations
 - Native location/ landscape for buffaloberry
 - drought / non-drought for mahogany and snowbrush
 - salt / non-salt for globe mallow

2. Identification of novel or enriched microbes from above comparative studies.

3. Isolation of identified microbes if possible, otherwise use the soil samples enriched with microbiome

4. Testing and identification of microbes on native plants at landscape for Buffaloberry and on *Arabidopsis* and *Medicago truncatula* in green house for drought tolerance and salt stress.

5. Transfer and testing of identified microbes on spinach, rice, maize, alfalfa and strawberry in green house and eventually in the field.

Target dates:

Objective 1

Collect soil and root samples of mountain mahogany and snowbrush *Ceanothus* plants in wild populations (2019)

Collect soil and root samples of round Buffaloberry and silver buffaloberry in wild populations and landscape (2020)

Collect soil and root samples of Globemallow plants from wild and salt affected locations. (2021)

DNA extraction, Library generation, Sequencing, and Bioinformatics analysis. (2019, 2020, 2021, 2022, 2023)

Objective 2

Comparative study to identify the microbes and publication of research and file for patents if applicable

(2020, 2021, 2022, 2023)

Objective 3

Isolation of identified microbes from respective rhizosphere or roots if possible, otherwise use the soil samples enriched with microbiome (2020, 2021, 2022, 2023)

Objective 4

Testing and identification of microbes on native plants at landscape for Buffaloberry and on *Arabidopsis thaliana* and *Medicago truncatula* in green house for biomass, drought tolerance and salt stress. (2020, 2021, 2022, 2023)

Objective 5

Testing of identified microbes on spinach, rice, maize, alfalfa and strawberry in green house and eventually in field. (2021, 2022, 2023)

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

As Objective 3 and Objective 4 for 2021 have changed. These objectives were

Collect soil and root samples of Globemallow plants from wild and salt-affected locations. Testing and identification of microbes on native plants at the landscape for Buffaloberry and on *Arabidopsis thaliana* and *Medicago truncatula* in the greenhouse for biomass, drought tolerance, and salt stress.

I modified this objective and focused on more detailed research on the snowbrush microbiome. We found exciting results from the Snowbrush study, and work has expanded on this plant.

Because of COVID19, we could not carry out a part of the target of 2020 for objective 1, and Objective 4. This target was to collect Buffaloberry roots and soil from the Southwestern desert. We collected sample in the spring, 2022.

The project on comparative analysis of the microbiome of bulk soil, the rhizosphere, the endosphere of *Ceanothus velutinus* (Snowbrush) plant, and the rhizosphere of greenhouse-grown snowbrush plants treated with native soil has been completed. One manuscript has been in the final stages of submission. The project for isolation, identification, and characterization of plant growth-promoting bacteria from the rhizosphere and endosphere of the snowbrush plant has been completed. One manuscript was published in the *Frontiers of Plant Sciences* in December 2022. We have shortlisted seven IAA-producing rhizobacteria from the snowbrush cuttings from the propagation experiment based on *Arabidopsis* studies. These microbes are being tested for cutting propagation. *Frankia* is reported to be the most abundant genus in the nodules of snowbrush *Ceanothus* by metagenomic analysis. The shortlisted microbes are being tested for plant growth promotion on drought and salt stress in wheat, maize, and tall fescue.

The findings have been presented as an e-poster and oral presentation at the American Society of Horticulture Scientists

(ASHS, Chicago) and Tri-society conference (ASA-CSSA-SSA, Baltimore in 2022.

Besides this, undergraduate and graduate students presented results at various university-level avenues, such as UCUR, 2022. Student Research Symposium, 2022, and Fall Student Research Symposium, 2022.

Data for grant proposals and manuscripts

The results from all these studies reveal a significant role of the microbiome of the snowbrush cutting propagation; we received funding to develop snowbrushes for the nursery using its microbiome from UDAF.

We submitted one proposal to USDA-NIFA- Agriculture Microbiome for \$850,000 in collaboration with UOU, Salt Lake City, and USDA-Salinity, Lab Riverside, California.

One manuscript has been published, and two are in submission.

We are preparing one more proposal to submit to UDAF.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

During this project, two undergraduate and two graduate students trained in various techniques in microbiology, plant biology, bioinformatics data analysis, and molecular biology. Two undergraduate students are involved in isolating and identifying microbes from rhizosphere soil and roots. One graduate student analyzes metagenomic data, and another isolates the Frankia from Nodules. Undergraduate and graduate students presented the work at national, international, and USU-level conferences.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

The objective of investigating Globemallow plants has changed. We found exciting results from the Snowbrush study, and work has expanded on this plant. So, I stopped studying the Globemallow plants and focused on more detailed research on the snowbrush microbiome.

Training and Professional Development:

Two undergraduate students and two graduate students are trained in various techniques related to plant biology, microbiology, bioinformatics, and molecular biology. Students, undergraduates, and graduates presented findings in various conferences and meetings as posters and oral presentations. Students learned to organize and analyze large-scale NSG data. Students are exposed to the basic problem of climate change and its effect on crop production and feeding the growing world population. Students learned the importance of Native plants and microbiomes and the role of the microbiome in plants' growth and development under stress. They learned to use natural resources to develop more stress-resilient crops without genetically modifying them. Students presented their work in weekly lab meetings and were involved in lab discussions about a topic related to their research areas.

Dissemination:

The project study trained many Undergraduates and graduates in various techniques involved in microbiology, molecular biology, and plant biology, such as

growing and propagating native plants in the greenhouse isolating bacteria from soil, nodules, and roots biochemical characterization of bacteria maintenance, and storage of microbes metagenomic analysis PCR amplification, sequencing, and BLAST search. We are testing the effect of microbes on various plants with and without salt stress in growth chambers and greenhouse conditions. The study exposed students to the importance of Native plants and natural resources. NSG data analysis for the microbial community in native plants' microbiome. We shared obtained results with the scientific community through various meetings and workshops. We received a federal grant to study the microbiome to develop native plants for

nurseries. We submitted one proposal to USDA-NIFA- Agriculture Microbiome for \$850,000 in collaboration with UOU, Salt Lake City, and USDA-Salinity, Lab Riverside, California. We published one part of the research in a reputed Journal, Frontiers of Plant Sciences (IF 6.627).

Products:

Other Products:

Data and Research Material - IAA producing plant growth promoting bacteria were isolated from the rhizosphere soil of the snowbrush ceanothus cuttings propagated with native soil. These isolated tested on Arabidopsis for the growth and development and seven bacteria shortlisted for further studies for cutting propagation. The cocktail of seven bacterial isolates has been tested for cutting propagation of snowbrush ceanothus. These isolates are also being tested on corn, wheat, tall fescue for plant growth and promotion. Abundance of Frankia found in the nodules of snowbrush ceanothus by metagenomic analysis. Bulk soil, rhizosphere and root samples has been collected for roundleaf buffaloberry from Colorado city and Cannonville from Southern Utah and Arizona border. DNA has been extracted for 16S rRNA sequencing. Bulk soil, rhizosphere and root samples has been collected from hybrid buffaloberry from USU campus, Greenville form and USU Botanical Garden at Kaysville Utah.

Plan of Work:

The plan of work for the next reporting period

Testing microbes isolated from the rhizosphere, roots, and nodules of snowbrush on Arabidopsis, alfalfa, wheat, and maize for plant growth and development. Testing shortlisted isolates producing IAA individually and in combination for the propagation of snowbrush cuttings. Submission of two manuscripts from snowbrush data in an appropriate journal. Submission of one more extramural funding proposal. NSG sequencing and Data analysis of the samples of Mahogany from Logan canyon. Metagenomic analysis and bacterial isolation from the bulk soil, rhizosphere, and roots (endosphere) of buffaloberry *Shepherdia rotundifolia* and *hybrid buffaloberry*. Presentation of results in USU, national, and international conferences

Closing Out (end date 06/12/2024)

Novel mechanism of flavivirus-induced temporary paralysis and rapid recovery

Project Director

J Morrey

Organization

Utah State University

Accession Number

1019614



Novel mechanism of flavivirus-induced temporary paralysis and rapid recovery.

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall goal is to discover how West Nile virus (WNV) and other flaviviruses cause paralysis. The specific objectives are:

Specific Aim #1. WNV peripheral neuropathy. The objectives for SA #1 are based on the hypothesis that WNV-induced motor deficits in a non-lethal mouse model are caused by a combination of peripheral neuropathy and synaptic retraction.

Objective 1. Determine the clinical relevance of increased % A-wave persistence (indicator of “leaky” axons in peripheral neuropathy) by determining the correlation with M-wave amplitude, % F-wave persistence, nerve conduction velocity, and histological peripheral neuropathy.

Objective 2. Verify that WNV-induced peripheral neuropathy as detected by % A-wave persistence is temporary and reversible.

Objective 3. Determine if WNV causes synaptic retraction seen in SA #2.

Specific Aim #2. Synaptic retraction in temporary paralysis caused by ZIKV. The objectives for SA #2 are based on the hypothesis that virus infects motor neurons to cause synaptic retraction, but infection is cleared upon recovery of paralysis.

Objective 1. Identify evidence of infection in motor neurons of paralyzed mice compared to mice without deficits or sham-control mice, and to verify that it is cleared upon recovery of paralysis and synaptic retraction.

Objective 2. Identify cellular and molecular responses associated with ZIKV infection and synaptic retraction.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Model #1 (WNV):

Objective 1. Determine the clinical relevance of increased % A-wave persistence (indicator of “leaky” axons in peripheral neuropathy) by determining the correlation with M-wave amplitude, % F-wave persistence, nerve conduction velocity, and histological peripheral neuropathy to paralysis.

Completed. No work done during this period.

Objective 2. Verify that WNV-induced peripheral neuropathy as detected by % A-wave persistence is temporary and reversible.

Completed. No work done during this period.

Objective 3. Determine if WNV causes synaptic retraction seen in model #2.

Completed. No work done during this period.

Model #2 (ZIKV)

Objective 1. Identify evidence of mild infection of motor neurons of paralyzed mice compared to mice without deficits or sham-control mice, and to verify that clearance of infection is coincident with recovery of paralysis.

Since alpha-motor neurons are not killed in this temporary acute flaccid paralysis model, an important question is if ZIKV mildly infects motor neurons below the limit of IHC detection or if indirect immunopathology causes the events leading to paralysis, or if it is a combination of both. The following item was done to answer the question:

- In the prior period, colorimetric *in situ* hybridization (ISH, RNAscope procedure) did not identify infection of motor neurons (ZIKV RNA) despite robust infection in other cells besides motor neurons. During this period, fluorescent *in situ* hybridization did detect ZIKV RNA in some motor neurons of paralyzed mice. However, no ZIKV RNA was detected in motor neurons of recovered mice within several days after paralysis. We are staining the same tissues by immunohistochemistry to determine if antigen is detected in the motor neurons of the same animals. The data indicate that recovery is coincident with clearance of the virus. Flavivirus-infected cells are usually killed to cause paralysis, but this does not seem to be the case with this model where the animals recover from paralysis and recover from intracellular infection.

In the proposal we stated that immuno-EM would be performed if *in situ* hybridization was inadequate to detect viral RNA in motor neurons. Since *in situ* hybridization was adequate, we did not perform immuno-EM.

Objective 2. Identify cellular and molecular responses associated with ZIKV infection and synaptic retraction.

In the prior period, we determined that choline acetyltransferase (ChAT) RNA was reduced 2- to 3-fold in paralyzed mice and ~4-fold in mice that had visually recovered from paralysis. The ChAT protein did not diminish as determined by immunohistochemistry (IHC) using confocal microscopy. NeuN and pre-synaptic synaptophysin expression were also altered in paralyzed and recovering mice using IHC.

Realizing that alteration of the expression of motor neuron proteins does not mean that this altered expressions are not likely

to cause paralysis, we performed two rounds of RNAseq and bioinformatics analysis on motor neuron-enriched samples from sham, paralyzed, and recovered mice with the help of Aaron Thomas (ADVS, USU) and Rakesh Kaundal (PSC, USU).

The current working hypothesis is that motor neurons are changed without having to be infected by the virus which renders the motor neurons inactive. Neuronal RNA transcription or degradation occurs during and after paralysis that may contribute to the mechanism of paralysis and recovery. Since the neurons are not infected, extracellular signals are probably mediators of these effect. In the first round, we identified thousands of differentially expressed genes (DEGs) in paralyzed mice, compared to sham and recovered mice. In a more robust second round using more mice for statistical power, we are currently identifying DEGs in paralyzed mice compared to gene expression common to sham and recovered mice. At this point we do not see evidence that altered expression of ChAT, NeuN, or synaptophysin are associated with paralysis. Using this genomics approach, we will be able to identify any candidate synapse proteins associated with synaptic retraction or paralysis.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The primary target was human and veterinary neurologists.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None this period.

Training and Professional Development:

This year we established a collatoration with Aaron Thomas for RNAseq and with Rakesh Kaundal for bioinformatic analysis.

Dissemination:

An invited Zoom oral presentation at the 3rd Latin American Congress on Neurosciences and Behavior (Sept 11-14) was given.

Plan of Work:

Model #1 (WNV): Work completed.

Model #2 (ZIKV)

Objective 1: Identify evidence of mild infection of motor neurons of paralyzed mice compared to mice without deficits or sham-control mice, and to verify that clearance of infection is coincident with recovery of paralysis. Work completed.

Objective 2. Identify cellular and molecular responses associated with ZIKV infection and synaptic retraction.

In the last reporting period, we stated that we should be submitting a manuscript within the next reporting period. Due to the added RNAseq and bioinformatic activities, this was not done. More bioinformatic analysis and IHC staining from sham, paralyzed, immediate recovery, 1-month recovery, and 2-month recovery mice still need to be done before the submission of the manuscript.



Improving small farm viability through high value crops and resource use efficiency

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The overall goals include:

- 1)Extend soil physics and crop physiology disciplines to a new crop category, cut flowers, to advance scientific knowledge and promote robust, mechanistic approaches in horticulture.
- 2)Generate and develop quantitative data into in-state best management practices to maximize yields, hence profits, and ensure long-term sustainability for Utah farmers.

The Objectives and timelines with expected deliverables include:

- I.Season extenders and soil heating on premium cut flower varieties to force earlier, and higher quality blooms.

2019-2021

- 1.Compare high tunnel to outdoor production of Peony and evaluate the influence of soil heating to advance early spring flower development, yields, and quality.
- 2.Develop flowering prediction models with environmental and plant growth data to schedule flower production that meets a specific marketing window and optimized flower yields in peony.
- 3.Disseminate research findings from peony studies to growers, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

2020-2022

- 1.Compare high tunnel to outdoor production of Dahlia and evaluate the influence of soil heating and shading to advance mid-season flower development, yields, and quality.
- 2.Develop flowering prediction models with environmental and plant growth data to schedule flower production that meets a specific marketing window and optimized flower yields in Dahlia.
- 3.Disseminate research findings from studies to growers, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

2022-2024

- 1.Compare fall to spring planting production of Ranunculus and Anemone and evaluate the influence of planting dates, soil temperature, and frost penetration on spring flower development, yields, and quality.
- 2.Develop flowering prediction models with environmental and plant growth data to schedule flower production that meets a specific marketing window and optimized flower yields in Ranunculus and Anemone.
- 3.Disseminate research findings from studies to growers, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

II.Nutrient management for viable, long-term cut flower production and environmental sustainability

(2019-2021 for Dahlia; 2023-2024 for Peony)

- 1.Develop nutrient rate recommendations for Dahlia and Peony cultivation through research trials with five nitrogen rates and data that include soil test results (nitrogen, phosphorus, potassium, pH, and salinity) and yield (date of first harvestable bloom, stem length, bloom diameter, and total number of blooms per plant) over two growing seasons.
- 2.Determine baseline production and profitability of Dahlia through a two-year on-farm study of soil test and yield data from six participatory farms. The growers span across a 200-mile transect in Utah that represents the diverse soil types and ranging climatic conditions, where the majority of the state's population resides and manages land (the Wasatch Front).
- 3.Raise soil health awareness and disseminate research findings from Dahlia and Peony studies to growers, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

III. Quantifying day versus night irrigation efficiency through soil moisture and surface microclimate measurements to develop urban crop coefficients and irrigation for cut flowers and traditional turf.

(2019-2022)

1. Identify whether a local water savings exists between day versus night irrigation scheduling with a water balance approach and relate findings to the quality of *Zinnia elegans*, a key ornamental crop for both cut flower growers and homeowners; and turf, the traditional urban vegetation
2. Develop crop coefficients to extend evapotranspiration research to cut flowers and improve irrigation efficiency.
3. Estimate irrigation water losses to wind drift and evaporation based on irrigation timing, urban vegetation type, canopy architecture from cut flower plantings, and weather conditions
4. Measure microclimate parameters that drive evapotranspiration – air temperature, humidity, and wind speed – during day versus night to provide scheduling recommendations
5. Disseminate research findings from studies to the public, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

(2022-2024)

1. Develop crop coefficients for Dahlia to continue and refine evapotranspiration research with cut flowers and improve irrigation efficiency, while accounting for stand architecture on irrigation water losses to wind drift and evaporation based on irrigation timing, urban vegetation type, and weather conditions.
2. Disseminate research findings from studies to the public, industry partners, and the wider horticultural community through journal articles, fact sheets, social media, and workshops.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Several studies are being conducted for this project and data collection is in progress:

- Determining plants dates, cultivar selection, season extension, harvest methods, and market preferences for key cut flower crops - we completed the field seasons and analysis for 2 cut flowers (ranunculus and anemone) and published two manuscripts. A third cut flower crop (peony) was analyzed and the paper submitted for review. It was accepted and is in press.
- Optimizing harvest timing for key cut flower crops - data collection in progress.
- Evaluating irrigation management for urban crops - data collection complete; analysis complete; the scientific article is in progress.
- Evaluating nutrient management practices for cut flower crops - data collection complete; analysis complete; the scientific article is in review.
- Evaluating plant pathology needs of cut flower crops - data collection and analysis in progress. One Extension fact sheet was written and published on this topic, as well as a newsletter article.
- Soil surveying urban environments for contaminants - data collection complete; analysis complete; scientific paper is in progress.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

- Cut flower farmers throughout Utah and surrounding regions.
- Urban public interested in ornamentals and home food production.
- Small farms interested in diversification.
- Urban farms and community garden leaders/managers.
- Refugees beginning to farm in Utah

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

- 1 graduate student graduated with an MS in Soil Science in Summer 2022, 1 graduate student graduated with an MS in Plant Science in December 2022, and 1 graduate student defended her MS in Soil Science in December 2022.
- One half-day session for cut flower growers at the Utah Urban and Small Farms Conference
- 1 field tour day at the research farm for small farms
- One presentation to county extension faculty on soil contamination and cut flower crops

Dissemination:

- 2 published academic, refereed papers published
- 9 peer-reviewed fact sheets published
- 3 nonrefereed articles published
- 3 national presentations at academic conferences
- 2 national presentations for stakeholders
- 1 regional presentation for granting agency
- 1 cut flower conference session for Utah growers
- 25 state presentations for farmers and homeowners
- 1 social media account that reaches Utah growers, as well as national, with high engagement rates

Products:

Publications:

Periodicals:

Nischwitz, C., & Stock, M. (2022). New diseases detected on Utah cut flowers. (Summer ed., vol. XVI, pp. 1-2). Logan, UT: Utah Pests Quarterly Newsletter, Utah Plant Pest Diagnostic Laboratory & USU Extension.

Other:

Chelinski, M., Stock, M., Grossl, P., & Oliver, E. (2022). Trace Element Contamination in Urban Soils: Testing and Management. (pp. 5). Logan, UT: USU Extension.

Collins, A., Stock, M., Lewis, M., & Hansen, S. (2022). Celosia Cut Flower Production in Utah. (pp. 5). Logan, UT: USU Extension.

Gleeson, S., Stock, M., & Nischwitz, C. (2022). Dahlia mosaic virus on dahlia. (pp. 2). Logan, UT: USU Extension.

Hansen, S., Drost, D. T., Stock, M., & Black, B. L. (2022). Expected Vegetable, Berry, Fruit, and Cut Flowers for Urban Farms in Utah. Logan, UT: USU Extension.

Lewis, M., Stock, M., Black, B. L., & Drost, D. T. (2022). Stock Cut Flower Production in Utah. (pp. 6). Logan, UT: USU Extension.

Rauter, S., & Stock, M. (2022). Evaluating Production Strategies for Anemone and Ranunculus in the Intermountain West. Alexandria, VA: American Society for Horticultural Science.

Rauter, S., Stock, M., & Ward, R. A. (in press). Ranunculus Cut Flower Production Budget, One Field, Northern Utah, 2022. (pp. 6). Logan, UT: USU Extension.

Stock, M., Pratt, A., Nischwitz, C., Oliver, E., Wagner, K. M., & Volesky, N. (in press). Dahlia Cut Flower Production in Utah. (pp. 7). Logan, UT: USU Extension.

Stock, M., Hansen, S., Lewis, M., Black, B. L., & Drost, D. T. (2022). Lisianthus Cut Flower Production in Utah. (pp. 6). Logan, UT: USU Extension.

Plan of Work:

- Publish academic articles on research findings - complete revisions for one accepted paper, submit 2-3 new papers for review and publication.
- Publish fact sheets - publish at least 6 peer-reviewed fact sheets in 2023 that span enterprise budgets, crop production methods, and small livestock management
- Continue presentation record in 2023, including field tours and national outreach events

The Economics of Specialized Agricultural Products: Contracting, Uncertainty, and the Value of Waiting

Project Director

Tanner McCarty

Organization

Utah State University

Accession Number

1018432



The Economics of Specialized Agricultural Products: Contracting, Uncertainty, and the Value of Waiting

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1 and 2) Activities and Objectives

I successfully accomplished my 1st stated objective of, refining and perfecting a contracting framework for specialized agricultural product (SAP) markets. I refined this working framework in Matlab that allows optimal contract structure to endogenously respond to uncertainty and irreversibility inherent within SAP markets while satisfying contractual constraints. I then worked on my second objective, measure the effect of these changing contractual structures on risk and return distribution throughout the vertical supply chain across various SAP markets. I applied my framework to a theoretical paper regarding contract structures response to different sources and sizes of uncertainty and irreversibility for SAPs. I also applied this model to an empirical paper regarding perennial energy crop contracting.

I additionally furthered my 2nd objective by researching aquaponic and industrial hemp markets. Aquaponics is an important SAP due to its high yields per acre, its low water requirement, and its utilization of previously untapped waste streams to promote plant growth. I worked with my master's student Grace Gibbons on developing budgets for various aquaponics' technologies. Once the profit maximizing technology and market characteristics are known for aquaponics, I can apply my contract optimization framework to that market.

Industrial hemp's new legal status combined with growing consumer demand for hemp-derived products offers the potential for the development of a new and lucrative agricultural SAP supply chain. Consumers, growers, and processors are especially interested in products derived from cannabinoids (e.g. cannabidiol, or CBD) present within the hemp floral material. CBD is a high value non-intoxicating cannabis molecule used in numerous high value therapeutic and cosmetic products.

Due to industrial hemp's potential importance, I worked on two separate papers aimed at understanding industrial hemp markets with the eventual goal of applying my contractual framework to them. The first, I used a real options framework to quantify the impact regional risk level, sunk cost, opportunity cost, and growing conditions each individually has on a farmer's decision to produce CBD hemp. The article characterized the regional economic and agronomic factors that are most important in determining the feedstock cost of CBD hemp.

The next article examined the reported issue of cross-pollination for CBD crops. Hemp CBD growers claim cross-pollination from neighbors growing cultivars designed for fiber or seed production destroy the value of their flower crop. The problem is, swelling applications and permits for fiber and seed production increase the likelihood of this negative externality. Without legislation, hemp CBD growers could be forced to switch to fiber or seed hemp which is unaffected by pollination. This

research helps me more accurately calibrate my framework to the complexities of industrial hemp and also supports my third objective of understanding contractual relationships in SAP markets to better inform agricultural policy within them. I collaborated on a paper examining the Pasture Rangeland and Forage Program. Despite federal support and an arid climate, many ranchers within the Intermountain West are reluctant to adopt the PRF insurance program. Some expressed concern of the program not making payouts during periods of poor forage availability. If these claims are true, it means that the PRF rainfall index may not accurately estimate forage availability for specific areas, failing to achieve its stated goal of helping to cover the replacement cost of feed during times of poor forage caused by lack of precipitation.

3) Results

Equilibrium contract structure is sensitive to both the source and level of volatility for SAPs. Additionally, we find that processors are more effective at achieving high returns under some sources of volatility than others. More specifically, existing contracting instruments can more effectively shape risk coming from the SAP itself, than risk coming from the lands alternative use. This means contracts are more effective at reducing premium on entry, when the risk comes from SAPs than when it comes from opportunity cost.

In the absence of contracting or policy, the risk and sunk-cost inherit to perennial energy crop production leads to price premiums of 50% (above breakeven prices). This premium is reduced to 15% under the cost minimizing contract structure that contains large lump sum payments and indexing payments. Additionally current subsidies designed to develop the cellulosic biofuel industry are not cost effective in their current form.

The most important factors in determining the price required to trigger CBD floral hemp production are the expected yield of floral hemp and CBD concentrations within it. CBD processors looking to secure affordable feedstock should prioritize regions supporting these factors. Under current state policies and cultivars, the Southern United States appears to be the most likely, of current major hemp production regions, to be capable of producing low-cost floral hemp. This is due to its relatively favorable growing conditions.

Cross-pollination reduces hemp floral price considerably. It only harms floral hemp producers and doesn't negatively effect fiber or seed hemp. Over time, a stable, sub-optimal Nash Equilibrium of reduced flower production results. Our analysis indicated the sub-optimal equilibrium is avoided through either an auction style quota for seed/fiber cultivars or agricultural zoning laws, which keep flower production sufficiently separated from other cultivars.

The consistent jump in rainfall indexes, used to calculate Pasture Rangeland and Forage Insurance, after the introduction of high altitude stations to an area warrants further inspection and policy maker attention. Based upon our study, we suspect the Rainfall Index to be an accurate approximation of grazing conditions in the relatively flat land of the South or Midwest but to be less reliable in the topographically diverse Intermountain West. The potential inaccuracies of the current Rainfall Index could be reduced by modifying the Rainfall Index itself or using the Vegetative Index as a double check on forage availability estimates.

4) Key impacts

The first two articles established how agricultural specialty crop producers respond to sunk cost and uncertainty. They also quantify how sunk cost and uncertainty are shaped through contract structure and how that contract structure responds to various market properties. This better helps producers and processors of specialty agricultural products sign mutually beneficial contracts. Which has the benefit of supporting supply chain development of new potentially economically important nascent industries as industrial hemp, energy crops, and aquaponics. This knowledge provides actionable policies to legislators looking to support development new agricultural supply chains on how to best work with private industry to foster supply chain development.

The third and fourth article built knowledge for both farmers and processors being profitable in the nascent industrial hemp market. The importance of avoiding hemp cross-pollination and growing CBD hemp crops on high value land has direct benefit to growers and processors alike. The fourth article in particular gives actionable policy proposals on how to avoid industry ruining cross-pollination to state legislators who are currently looking to enact policy for newly federally legal industrial hemp crops.

In the fifth paper, we discovered that the Pasture Rangeland and Forage Insurance designed to protect ranchers from low rainfall doesn't appear to always provide the coverage it advertises. We provide propose reinstating the previously used Vegetation Index as a consistency check for the Rainfall index could reduce potential inaccuracies in payouts.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Activities and Objectives:

I furthered my second goal of “measuring the effect of these changing relationship structures on risk and return distribution throughout the vertical supply chain in various markets”. I also contributed to my third goal of “use the understanding of these relationships to more richly analyze policy aimed at improving agricultural outcomes in the United States.” I had an article accepted in the *American Journal of Agricultural Economics*. I also had an article with a student co-author accepted. I also submitted an additional three articles to journals this year (two of which are under review) and one of which was rejected after a split decision.

Article 1: “Adapting Network Theory to Fit Spatial Network Externalities in Agriculture: A Case Study on Hemp-Cross Pollination” (accepted, *American Journal of Agricultural Economics*). This article supports my third goal. The first is that it quantifies problem of cross-pollination across different hemp cultivars to inform agricultural policy interventions within this market. This paper used two novel datasets to estimate the geographic network that ties various farmers together and calculate the cost effectiveness of reducing pollination in hemp plants across various policies.

Article 2: “Milner Ranch: Is the Grass Greener in Processing?” (accepted, *Applied Economics Teaching Resources*) My co-authors and I worked with Albion Ranch to determine whether building a small to mid-scale beef processing plant made economic sense for cattle feedlot owners. This article supported my second goal by setting up and exploring the various ways that a meat processing plant can maintain relationships with cattle producers through either contracting or vertical integration.

Article 3: “The Economics of Specialized Agricultural Products: Contract Farming Under Uncertainty and Sunk Costs” (sent to reviewers and rejected after split decision). This article was rejected at a quality journal after a split reviewer decision. I am updating it to send to a different journal. This article uses my developed contractual framework for specialized agricultural products to examine how transactional attributes such as degree of moral hazard or relative degree of risk determines optimal contract structure for these products. It also models how these contract structures are affected through policies that limit specific contract mechanisms and how this resulting structure affects farmer, processor and societal welfare.

Article 4: “Modeling Soybean Planting Decisions: Does Herbicide Drift Affect Farmer Profitability and Seed Selection?” (under review). This article explored off target Dicamba herbicide drift for soybeans and estimated how it may affect farmer soybean seed selection within a region over time. This article loosely ties with my third goal by examining and quantifying relationships among farmers to improve understanding of seed selection decisions, externalities pertaining to drift and potential policy response aimed at improving outcomes in the market for U.S. Soybeans.

Article 5: "Techno-economic analysis of phosphorus removal structures" (under review). This work conducts a techno-economic analysis (TEA) to compare various phosphorus abatement technologies to identify the most cost effective choice for reducing phosphorus runoff. This technology is not by itself going to be attractive to farmers as reducing phosphorus runoff doesn't currently enhance their profitability. There is future work to be done to look at various mechanisms policymakers could offer farmers to adopt this technology. That work would support my second and third goal.

Results:

Article 1: We find that network structure is an important factor in externality size and cost-effective policy response for spatial agricultural network problems. We also find that policy implemented early and proactively is more likely to be successful and cost-effective than policy implemented retroactively. Finally, we find that in our application of limiting the cross-pollination damage high-cannabinoid hemp growers experience from fiber and seed hemp growers, the most cost-effective policy is to establish a regional quota on non-floral production combined with intertemporal cultivar spacing.

Article 2: Mid-scale beef processing plants are expensive to build and small scale plants suffer from a lack of scale. We find that the most realistic way for a cattle feedlot to incorporate a mid-scale processing plant into their operation is to form a co-op with other producers in the area. A co-op reduces liquidity constraints and limits risk exposure for any individual firm.

Article 3: We tested numerous assumptions to come up with insights for a wide range of specialized agricultural products. We find that limiting contractual mechanisms such as indexing payments and production contracts benefit the farmer at the cost of the processor but do not have any meaningful impact on total surplus between the two. These contract mechanisms affect how the economic pie gets divided not its size.

Article 4: We find that the damage associated with Dicamba drift and the subsequent impact that damage has on soybean seed selection decisions varies drastically by regions. Regions with low density grower networks had an average yield loss per field of about 1% as where high density networks experienced yield losses of over 9%.

Article 5: We found that out of the eight technologies considered, that a surface bed combined with metal shavings and gravel is likely to be the most cost-effective technology in reducing phosphorus runoff. This technology also had over a 30% reduction the average cost of per pound phosphorus abatement than the next most attractive technology under baseline assumptions.

Key impacts:

Article 1: We find that the most cost effective policy tool to fix hemp cross pollination is establishing a quota system for fiber producers. Our developed framework has use for other spatially based agricultural network externalities such as herbicide drift or GMO contamination in organic seed. It is also directly relevant to policy makers looking to reign in hemp cross pollination problems in the most cost effective way possible.

Article 2: case study pushes students to conceptualize and analyze the key economic tradeoffs (revenue, cost, risk, etc.) that come with expanding an agricultural firm's boundary. It also provides practice with examining the strengths and weaknesses of various transactional arrangements between producers and processors (marketing contracts, co-ops, and vertical integration).

Article 3: We have an improved idea of how the contract structure itself changes between a farmer and processor when contractual constraints are implemented. This allows us to estimate surplus of each group and surplus as a whole under various policy interventions. The fact that regulation doesn't affect total surplus should be particularly interesting to policy makers.

Article 4: Our framework estimates the total damage occurring from Dicamba drift and associated impacts for any given region. Effective policy needs to understand the benefits and costs to any potential action. This is especially the case when damage can vary so much across different regions. Our framework allows customized region-specific policy that is necessary to efficiently resolve Dicamba drift.

Article 5: Phosphorus runoff is an increasing problem within American agriculture. Previous attempts to reign it in have been unsuccessful in part because of how expensive they were to implement. By identifying which available technology is likely to be the cheapest to implement, policy makers can maximize phosphorus abatement while minimizing cost to farmers and/or taxpayers.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

My primary audience for this reporting period was academic researchers and policy makers as that is where most of my research gravitated towards. However I published one article and started two others that have a student and industry audience in mind.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

I didn't encounter any major problems this past year. I was able to solve and address issues as they came up.

Training and Professional Development:

Grants:

This past year I was awarded a \$94,000 grant from Utah's Department of Energy Development as principal investigator. The project was entitled "The Economic Contribution of Utah's Energy and Mining Industries". I worked with my co-PI's Man-Keun

Kim and James Evans (USU Geology Department) and a Ph.D. student, Zuyi Wang to estimate how much Utah's mining and energy industries contributed to the state economy in terms of GDP, employment and taxes in 2019 and 2020. The project went great. It was peer reviewed by an outside economist and was recommended for publication through the office of Energy Development. It has been published through Utah's office of energy development.

I also applied as a co-PI to a "Commodity Smart" grant through the USDA. This is a massive grant worth \$5,000,000. I would be in charge of \$1,000,000 of it if awarded. I am working with numerous researchers from Verdant Robotics, a startup precision agriculture company that uses machine learning to identify weeds and spot spray. The title of our grant was "Greenhouse Gas and Carbon Sequestration: A Specialty Crop Case Study". My part of this project would cover a wide range of topics including TEA for the technology, network theory to promote adoption, and crop rotation optimization with and without the technology. We are hoping to hear back on the award status of this grant this fall.

The third grant I applied to this past year was entitled "Sustainable propagation and establishment of young, grafted *Pinus edulis* for optimal pine-nut crop production on and off western U.S. tribal lands" This was an application for a SARE grant that I worked on with multiple researchers and extension agents within the Utah State University system. We did not get this grant but I am proud of the application we put together.

Conferences and workshops:

This past year I presented research at the academic conference, American Agricultural Economics Association "Does Herbicide Drift Exacerbate Input Supplier Concentration in the Market for U.S. Soybean Seed?" This presentation was well attended and received positive feedback. I also received some helpful suggestions from attendees at the talk that should help to continue driving this research forward.

Dissemination:

Published Papers from the Past Year

Young, J., & McCarty, T. (accepted) Adapting Network Theory to Fit Spatial Network Externalities in Agriculture: A Case Study on Hemp Cross-Pollination. *American Journal of Agricultural Economics*

Lee, W., McCarty, T., Thayer, A., Larsen, R. (accepted) Milner Ranch: Is the Grass Greener in Processing?. *Applied Economics Teaching Resources*

Invited Conferences and Seminars from the Past Year

Weed Science Society of America Annual Meeting (Vancouver, BC) Spring 2022 "Using Network Effects to Describe the Rate of Herbicide-Resistant Soybean Adoption Among Neighbors" (co-author presented)

Agricultural and Applied Economics Association (Anaheim, California) Summer 2022 "Does Herbicide Drift Exacerbate Input Supplier Concentration in the Market for U.S. Soybean Seed" (presenter)

ASA, CSSA, SSSA International Annual Meeting (Baltimore, Maryland) Fall 2022 "Techno-Economic Analysis of Phosphorus Removal Structures" (co-author presented)

Presentations:

McCarty, T. (Presenter & Author), Young, J. (Author Only), American Agricultural Economics Association 2022, "Does Herbicide Drift Exacerbate Input Supplier Concentration in the Market for U.S. Soybean Seed?," American Agricultural Economics Association, Anaheim California. (August 2022 - Present)

Plan of Work:

I plan on ultimately getting two additional papers out of this Dicamba research. I am in the early stages of a second paper on the topic that explores potential interaction between these network effects and market power for soybean seed suppliers. The working hypothesis is that with agricultural input suppliers already so consolidated, pushing more farmers into adopting a particular seed may make market power even worse. So far, we have developed the conceptual model and have econometrically estimated the market demand for soybean seed. I also plan to begin research on a third article that focuses on cost-effective policy analysis aimed at curbing the Dicamba drift problem once the second article is completed.

I am currently chairing two master's student committees where my students are working on industry focused research. One student just defended his thesis on contracting for oil seed crops for a company based in southern Idaho, Mountain State Oilseeds. The research went well and I plan on refining it into a case study based article that I hope to have under review

before the end of the year. My second student is working on research that identifies the best possible target market and marketing strategy for an agricultural technology firm here in Utah. The company, Renaissance Agriculture, has developed a hydroponic system that produces large amounts of livestock feed using small amounts of land and water. While my student won't defend their thesis until the spring, their abstract has already been accepted at a teaching journal during a call for submission.

I also plan on editing and re-submitting article #3 to another journal. Being that this article was already written, I just need to update it with the past reviewers comments to refine it and get it back under review. I plan on having all research discussed in this section under review by the end of 2023. If I am able to accomplish this, then next year should be a very productive year as well.

Soil Microbial Carbon-use Efficiency in Legume and Grass Pastures

Project Director

John Stark

Organization

Utah State University

Accession Number

1016191



Soil Microbial Carbon-use Efficiency in Legume and Grass Pastures

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Our project will utilize novel ^{13}C and ^{15}N isotopic techniques developed by our research group to examine the interactive effects of vegetation type, C and N substrate supply, and soil moisture on microbial carbon-use efficiency (CUE) in agroecosystems of Northern Utah. We will determine the effects of nitrogen-fixing legumes vs perennial grasses in irrigated pasture, with and without inorganic N fertilization on soil microbial CUE. More specifically, the objectives of our field and laboratory studies will be to determine:

- 1) If microbial CUE differs in soils beneath two legume species (birdsfoot trefoil and cicer milkvetch) and a perennial grass (meadow brome, with and without N fertilization) in intact plant-soil systems in the field.
- 2) How C- vs N-limitations to soil microbes influence CUE; and
- 3) How CUE changes with soil moisture, and if this effect is related to diffusion of substrates or the adverse physiological effects associated with low water potential.
- 4) If mathematical models can be developed that adequately describe the effects of nutrient availability and soil moisture on CUE.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

This year we were finally able to get a technician from the UK to complete the installation of the upgrade to our isotope-ratio mass spectrometer. The system was finally running at specs in April 2022, and we were able to begin analyzing the large number of soil and plant samples that we had accumulated during the period the system was inoperable. By the end of 2022, we had finished analyzing nearly all of the samples. Additional progress was made on a study examining the role of microbial C-use efficiency (CUE) in regulating rates of microbial decomposition of grass residues and in controlling the immobilization of N during this decomposition. This past year we produced large amounts of ^{15}N -labeled grass (crested wheatgrass) shoots and roots with both high and low C:N ratios. These plant materials are currently being incubated either on the surface or in the subsoil of soil mesocosms to determine how plant litter quality (i.e. varying tissue C:N) versus decomposition site location (i.e. above- vs belowground) influences decomposition rate, microbial C-use efficiency (CUE), and N immobilization. The mesocosms are being harvested at various time intervals (2-week to 6-mo intervals) to determine decomposition rates and

movement of C and N into the decomposing litter or out into the adjacent soil. Two manuscripts are currently in preparation: the first examines how CUE and N immobilization rates are affected by pasture vegetation type (bird's foot trefoil vs meadow brome grass) and N fertilization rates. The second manuscript examines the relationships between CUE and soil moisture in soils of four different textures. The goal of this second manuscript is to develop a simple model that will allow prediction of how CUE changes with soil moisture across a wide range of soil types.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Ecologists, biogeochemists, agricultural managers, soil scientists

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None.

Training and Professional Development:

The PhD student on the project has been trained in research techniques, including ^{13}C -isotopic analyses of gases (CO_2) using a state-of-the-art Picarro cavity ring-down spectrometer, which measures ^{13}C enrichments of CO_2 in real-time, at ambient atmospheric concentrations. She has also been serving as the lab manager in charge of the analytical equipment, maintaining and supervising use of our Lachat flow-injection autoanalyzer and the Picarro system, and she has been the primary liaison handling upgrade and running of the isotope-ratio mass spectrometer. In Dec 2022, she interviewed for a faculty position at North Dakota State University.

Dissemination:

We continue to work on manuscripts reporting our findings on vegetation, nutrient, and soil moisture controls on CUE and microbial immobilization of N. The PhD student presented her results as part of a job interview at North Dakota State University in Dec.

Presentations:

Butcher, K. R. (Presenter & Author), Stark, J. M. (Author Only), MacAdam, J. W., Nasto, M. K., Branch Meeting of the American Society for Microbiology, "Mechanisms for soil moisture effects on microbial carbon-use efficiency," American Society for Microbiology, Provo, UT. (April 13, 2019 - Present)

Plan of Work:

In this final year of the project, we will continue harvesting of the mesocosms being incubated in the decomposition study, and analyzing the plant and soil samples resulting from these harvests. After the sample analyses are completed, we will carry out statistical analyses and write at least one manuscript reporting the results. In addition, we will present the results at national meetings, and complete drafts of manuscripts already in progress for peer-reviewed journals.

Switching Sex to Apomixis in Crops

Project Director

John carman

Organization



Switching Sex to Apomixis in Crops

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Through pharmacological studies, we demonstrated that apomeiosis, parthenogenesis and autonomous endosperm formation (the three elements of apomixis in angiosperms) are metabolically inducible at high frequencies in sexual *Arabidopsis thaliana*, sexual *Boechera stricta* and sexual cowpea. Through expression profiling experiments, we identified candidate genes that should accomplish the targeted metabolic modifications when engineered into crop plants. Engineering these candidate genes into crops so that apomixis is induced constitutes the major goal of the current proposal. we propose to:

1. Select and clone 8-10 candidate genes based on expression profiling and results of subsequent pharmacological studies (July,2020).
2. Acquire promoters that will express the candidate genes in ovule cells and tissues (Dec, 2020).
3. Combine selected promoters and candidate genes into transformation constructs (July 2021).
4. Engineer the designed cassettes into *A. thaliana* and evaluate their effects in terms of inducing apomeiosis, parthenogenesis and autonomous endosperm formation (July, 2022).
5. Engineer constructs that induce apomixis processes in *Arabidopsis* into maize and soybean and evaluate levels of apomixis expression (July 2023).

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Major activities completed. Additional procedures for chemically inducing apomeiosis (unreduced gametophyte and gamete formation) in cowpea were developed.

Specific objectives met. Objectives 1-4: select and clone apomixis candidate genes, build constructs using appropriate promoters, transform constructs into *Arabidopsis*, and phenotype the transformants. Of 20 apomixis pathway involved candidate genes, two different knockouts for eight of these genes were embryologically phenotyped. Objective 5: genetically engineer maize with apomixis inducing constructs. In preparation for this objective, We completed an RNASeq experiment involving chemically induced apomeiotic immature maize cobs versus control cobs.

Significant results achieved, including major findings, developments, or conclusions (both positive and negative). High? frequency apomeiosis has been initiated in all sexual species tested so far: Brassicaceae family, *Boechera stricta*, *Boechera exilis*, and *Arabidopsis thaliana*; Fabaceae family, *Vigna unguiculata* (cowpea) and *Glycine max* (soybean); Asteraceae family, *Antennaria dioica*, Poaceae family, *Zea mays* (corn). Unreduced gametophytes formed from ameiotic female and male sporocytes, first division restitution dyads, and nucellar cells. These results are consistent with modes of reproduction and types of apomixis, in natural apomicts, being regulated metabolically.

Key impacts or other accomplishments realized. Developing hybrid crops whose seeds are clones of the mother hybrid (apomictic hybrids) will reduce by 80 % hybrid seed production costs for crops that are currently grown as hybrids, a savings of \$800 M per year for U.S. hybrid corn seed producers alone. Additionally, it will enable superior yielding hybrid seed production for crops currently grown as varieties, due to the prohibitively high cost of generating commercial quantities of superior yielding hybrid seed. This could generate an annual value added of over \$30 B annually for wheat and rice alone. We have reported pharmacological induction of unreduced egg formation (apomeiosis, first step in apomixis) in eight sexual species from four families of angiosperms, including maize, soybean and cowpea. The publication reporting on maize and soybean (in preparation) will also report the use of megasporocyte and gametophyte specific molecular markers to verify apomeiosis induction in the sexual model plant *Arabidopsis*.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Scientists and seed companies investigating plant reproduction and genome evolution.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Due to retirement, this project concluded a year early

Training and Professional Development:

Our research findings have largely been made and elucidated by undergraduate and graduate students. These students have participated in preparing and writing up their findings for publication and are included as authors on several papers. One undergraduate student in my lab applied for and obtained an URCO undergraduate research grant to further elucidate the molecular biology of apomeiosis induction in maize, which she has now completed (included an RNASeq study discussed above) Much professional development, in terms of understanding and applying molecular biology, is occurring as a result of multiple informal one-on-one meetings and discussions among molecular biology trained professors in the PSC department.

Dissemination:

provisional patent filed in February

Plan of Work:

This is a final report

Exploring the role of mitochondria in postmortem meat tenderization

Project Director

Sulaiman Matarneh

Organization

Utah State University

Accession Number

1015331



Exploring the role of mitochondria in postmortem meat tenderization

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective

The overall objective of this project is to define precisely the role mitochondria play in meat tenderization during meat aging and to identify new biomarkers associated with variations in meat tenderness.

Specific Aim #1: Determine mitochondrial role in postmortem calcium regulation and its effect on proteolysis.

Specific Aim #2: Identify the contribution of mitochondria to postmortem apoptosis and its significance to meat tenderness.

Specific Aim #3: Examine differences in the proteomic profile between red-oxidative and white glycolytic muscle.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The overall objective of this project was to define precisely the role mitochondria play in meat tenderization during aging and identify biomarkers associated with variations in meat tenderness. This research project consists of three aims:

Specific Aim #1

The purpose of this research was to examine the role of mitochondria in postmortem calcium homeostasis and its effect on meat proteolysis and tenderness. We hypothesized that mitochondria buffer cytosolic calcium and delay the activation of calpain-1, the major protease responsible for postmortem proteolysis and meat tenderization. To test this hypothesis, bovine muscle samples were injected with DS16570511 to inhibit mitochondrial calcium uptake. Free calcium, calpain-1 activity, proteolysis, and tenderness were evaluated over a 336-h aging period. Inhibition of mitochondrial calcium uptake increased cytosolic calcium concentration and calpain-1 autolysis and activity compared to control steaks. Further, proteolysis and tenderness were enhanced in the treated steaks. Collectively, these data indicate that inhibition of mitochondrial calcium uptake enhances postmortem proteolysis and tenderization through an early activation of calpain-1. This research is important because it is among the first to investigate the role of mitochondria in postmortem proteolysis and beef tenderization. An article detailing the results of this research was published in Meat Science.

Specific Aim #2

The goal of the research proposed under research objective #2 was to determine the contribution of mitochondria to postmortem apoptosis and meat tenderness. To achieve this goal, beef steaks were subjected to ultrasonication treatment and subsequently aged for 14 d. Ultrasound was used to compromise mitochondria through inducing the formation of mitochondrial permeability transition pores and through physical disruption in order to accelerate apoptosis. Ultrasonication improved beef tenderness without negatively impacting pH, color, or cook loss. Tenderness improvement was associated with greater degradation of titin, desmin, troponin-T, and calpastatin and increased calpain-1 autolysis and caspase-3 activity (the main apoptotic protease). In addition, ultrasonicated steaks had greater levels of cytosolic calcium and reactive oxygen species and a lower mitochondrial oxygen consumption rate. These data indicate that improved beef tenderness following ultrasonication is, in part, a function of increased calpain-1 and caspase-3 activities, potentially by elevating cytosolic calcium and inducing mitochondrial dysfunction, respectively. This research is valuable because it addresses not only molecular aspects related to the development of meat tenderness, but also a technique that can be utilized to improve tenderness. An article detailing the findings of this research project was published in Meat Science.

The in vitro studies of aims 1 and 2 have also been completed and will be combined in one manuscript, which is in the final stages of preparation for submission.

Specific Aim #3

This objective aims to compare differences in the proteomic profiles of four different muscles known to vary in mitochondria abundance and tenderness, with the intention to identify proteins related to beef tenderness/toughness. These muscles are: masseter (red-oxidative), longissimus lumborum (intermediate), biceps femoris (intermediate), and cutaneous trunci (white-glycolytic). Proteins related to muscle contraction, calcium signaling, metabolism, extracellular matrix organization, chaperone, and apoptosis were differentially abundant between the different muscles. The established proteomic database obtained in this study will provide a reference for future research regarding potential protein biomarkers associated with meat tenderness. I anticipate submitting a manuscript detailing the results of this research before the end of 2021.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report

Training and Professional Development:

This project provided training activates for 13 undergraduate and 4 graduate students.

Dissemination:

Journal articles:

D.S. Dang, C.D. Stafford, M.J. Taylor, J.F. Buhler, K.J. Thornton, S.K. Matarneh. 2022. Ultrasonication of beef improves calpain-1 autolysis and caspase-3 activity by elevating cytosolic calcium and inducing mitochondrial dysfunction. *Meat Science*, 183:108646.

D.S. Dang, J.F. Buhler, H.T. Davis, K.J. Thornton, T.L. Scheffler, S.K. Matarneh. 2020. Inhibition of mitochondrial calcium uniporter enhances postmortem proteolysis and tenderness in beef cattle. *Meat Science*, 162:108039.

In addition, we have two more manuscripts that are in the final stages of preparation for submission.

Presentations:

I presented findings from this research at three different universities and at a USDA multistate meeting. In addition, my four graduate students presented data from this project at national conferences. Three of my undergraduate students also presented at the USU undergraduate research symposium.

Dissertation

David S. Dang. 2021. Role of Mitochondria in Postmortem Proteolysis and Meat Tenderness.

Plan of Work:

Two more manuscripts related to this research are currently being prepared for submission. I anticipate submitting them before the end of 2022.

Integrated Onion Pest and Disease Management

Project Director

D Drost

Organization

Utah State University

Accession Number

1014581



W3008 Integrated Onion Pest and Disease Management

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The work proposed herein is critical for solving the most important pest and disease problems that the US onion industry is facing. We are not aware of other public or private entities that will be organized across state borders to solve these problems and given the successful foundation set by previous multistate projects (W1008 and W2008), similar advancements are expected here. We anticipate that results from this research and extension effort will continue to contribute significantly to science as we communicate new knowledge about the biology, ecology and management of these pest and disease

organisms through peer-reviewed publications, presentations at professional meetings, and other outreach to stakeholders. OBJECTIVES: We will address these concerns through the following objectives: 1) Evaluate onion germplasm for resistance or tolerance to plant pathogens and insect pests; 2) Investigate the biology, ecology and management of onion thrips and other pests; and 3) Facilitate discussions among W3008 participants and onion industry stakeholders that will advance onion pest and disease management. OUTPUTS: Create detailed understanding of the extent and nature of genetic diversity of the pathogen causing economically important diseases such as Iris yellow spot virus. Identify new methods of detection, inoculation, and/or screening for the virus and thrips pests.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Help Dr. Claudia Nischwitz with her bacterial disease efforts associated with the “Stop the Rot” project (2019-2022). We maintained her field trials (planted, watered, weeded, fertility, etc.), advised her on maturity dates, and help with finding storage for the trial. Assisted in evaluations on how bacterial applications impacts bulb productivity (pre- and post-storage).

Planted onions to evaluate the role of plant population on onion productivity (2020-2021). Studies involved evaluation of stand emergence (every-other-day evaluations), early growth (monthly), and how this affects late-season bulb size variability. As seedlings emerged, plants were marked and then later in spring/summer, evaluated for early growth. By season's end, individual plants were harvested, sized, and weighed to determine how emergence affects late-season bulb size variability. At harvest tracked onion bulb size/weight variability and related that back to plant position and emergence data. Data in 2020 was compromised due to COVID travel restrictions.

Helped Niel Allen (USU Extension Irrigation specialist) from 2019-2021 as we evaluated how irrigation methods (Furrow and Drip) affect bulb productivity (part of Utah Water Initiative). Use a range of soil moisture monitoring devices to track consumptive water use in onion and assisted in field yield measurements while the growers were lifting and windrowing the crop to determine productivity.

Planted onion varieties at two locations in Northern Utah (2018, 2019, and 2022). Assessed establishment, early growth, adaption, maturity, and productivity and evaluated these lines' tolerances to IYSV and other diseases. Analyzed yearly data, compiled research findings, wrote yearly reports and shared this with cooperating companies, growers, and Utah Onion Association members. A total of 85 commercially available onion entries were evaluated.

All Utah members of the W3008 working group (Drost, Nischwitz, and Alston) received "Excellence in Multistate Research Award" from the Western Association of Agricultural Experiment Station Directors (July 2018) for their efforts in promoting and improving onion production in the US.

Worked with Utah onion growers to solve problems critical to their respective farms. On average made 15-20 contacts per year.

Participated in grant writing of a Utah Extension Grant (2020-2021) onion project titled “Improvements in Onion Plant Populations – Interactions with Irrigation”. Projected funded – \$20,000).

Participated in grant writing of a Utah Specialty Crop Block Grant (2019-2022) onion project titled “Early detection of the allium leaf miner (*Phytomyza gymnostoma*) in Utah”. Projected funded – \$25,000) with Claudia Nischwitz as the local PI.

Participated in grant writing (lead – Washington State Univ) for USDA-NIFA-SCRI onion project titled “Stop the Rot - Combating onion bacterial diseases with pathogenomic tools and enhanced management strategies (projected funded – Utah received \$150,000) with Claudia Nischwitz as the local PI.

Participate in grant writing (lead organization - Texas A&M) a USDA-SCRI planning grant titled “Onion Management - 21st century Tools”. Project was not funded.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

First - Utah onion growers, onion shippers and packers, and associated groups important to and associated with onions.

Second - US onion industry and associated groups. Other groups targeted: cooperative extension specialists, county extension staff, state (Dept. of Agriculture and Food), and Federal (NRCS, Risk Management) agencies interested in onion production information, at the local, regional, and national levels.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

In general, there were no significant challenges that affected work or research efforts during the five-year period of this project. In some years, spring conditions caused delays with onion planting but once planted, data collection was regular and work was regular and normal. The COVID year of 2020 was a bit more challenging given early COVID restrictions. As we figured out things locally, trialing was not too greatly affected but travel restrictions did limit some work and grower interactions until a management plan was finalized and approved. Overall, conditions in Utah were much better than those reported by colleagues in other states associated with the W3008 working group. We did miss some critical early data collection that limited our understanding of established relationships with later-season growth and yield. However, we continued the study in 2021 and were able to pick up what we needed to make the final project meaningful to the industry.

Training and Professional Development:

Shared research findings from 2021 with the Utah Onion Growers at the 2022 Winter Meetings (Feb. 8, 2022). 38 growers, industry leaders, and agency employees attended (in-person event). Topics covered; Stop the Rot Update, Seed Priming and Plant Populations; Fusarium Bulb Rot in Onion; Onion Stands and Stunting: the Causes (guest speaker); National Onion Association Update (guest speaker), and grower discussions (Issues for 2022).

Shared research findings from 2020 with the Utah Onion Growers at the 2021 Winter Meetings (Feb. 19, 2021 – held virtually due to COVID). 33 growers, industry leaders, and agency employees attended via ZOOM. Low participation due to ZOOM, which several growers complained about. Topics covered; Stand variability and crop productivity; Onion Leaf Miner update; Onion Water Use; Crop Insurance Update (guest speaker), and 3008 regional research report “Stop the Rot” (guest speaker).

Shared findings from 2019 with the Utah Onion Growers at the 2020 Winter Meetings (Feb. 11, 2020); Brigham City, UT (43 growers, industry leaders, and agency employees attended). Meetings conducted pre-COVID lockdown. Topics covered; Stand variability and crop productivity; Onion Leaf Miner update; Onion Water Use; and 3008 regional research report “Stop the Rot”.

Shared findings from 2018 with the Utah Onion Growers at the 2019 Winter Meetings (Feb. 12, 2019); Brigham City, UT (45 growers, industry leaders, and agency employees attended). Dr. Bruce Searle (Crop & Food New Zealand) was the keynote speaker Topics covered; Overview of onion production in NZ (guest speaker); Stand Variability and Crop Productivity (guest speaker); 2018 Onion Variety Trial; Common Bacterial Disease of Onion; and Update on 3008 regional meeting.

Organized and participated in Utah Summer Field Day (August 9, 2022 - 32 growers) in Box Elder County, UT. Organized and participated in Utah Summer Field Day (August 10, 2021 - 40 growers) in Weber County, UT. No summer field day was held due to COVID restrictions (August 2020). Organized and participated in Utah Summer Field Day (August 14, 2019 - 43 growers) in Weber County, UT. Organized and participated in Utah Summer Field Day (August 7, 2022 - 65 growers) in Box Elder County, UT. Viewed local onion research trial sites, met with onion representatives and held discussions on onion-related topics (activities and projects viewed vary by year).

Utah research report presented at W3008 meetings in Denver, CO (March 1, 2022), Virtual Meetings (2020 & 2021), Madison, WI (Jul 24, 2019), and Kennewick, WA (November 13-14, 2018).

Dissemination:

Since 2018, USU has been involved in and associated with the “Stop the Rot” project. Through monthly ZOOM meetings, project planning and data sharing occur with other members of the onion research community. Dr. Nischwitz is the USU project leader and activity participates in these meetings, my role is to assist where needed. Local findings from USU research and production are shared with all national participants. Local growers benefit through yearly educational meetings, yearly field days, personal on-farm visits, and information transfer from local, regional, and national sources.

USU onion research was shared with Utah and national onion growers at the 2019 International Allium Conference (Jul 25-27) held in Madison, WI. Poster presentations from Utah research (Nischwitz, Allen, and Drost) were presented to this international audience.

In 2018, I was an invited keynote speaker at the New Zealand Onion Grower Meetings (May 2018) in Ashburton (South Island) and Pukekohe (North Island), New Zealand. More than 100 growers, industry leaders, and agency employees attended. Topics presented to these growers covered creating sustainable production practices using Utah and W2008 and 3008 regional research findings. In addition, while in New Zealand I was a keynote speaker at the LandWISE Conference (125 attendees), in Hawkes Bay, New Zealand. (<http://www.landwise.org.nz/events-2/past/landwise-2018-technologies-for-timely-actions/landwise-2018-programme/>). The presentation title was “Sustainable Crop Production: Field and Farmscape Management of Onions”.

Each year, USU researchers and extension persons have individual discussions with local and regional onion farmers during Utah Field days (August 2018-2022) and winter meetings (February 2018-2022). Average attendance at yearly field days is 35-40 persons. Average attendance at yearly winter educational meetings is 40-45 persons. These events shared USU onion research with growers, stimulate new problems that the industry needs help with, and introduces local growers to what others are working on.

Plan of Work: Project Objectives:

Address Utah's local onion industry needs through 1) Evaluation of novel and new approaches to managing bacterial rots (Nischwitz/Drost); Utah's contributions to the USDA-NIFA “Stop the Rot” initiative. 2) Identify new/existing onion varieties and management approach for the important production regions in Utah (Drost); 3) Facilitate discussions among W3008 participants and local onion industry stakeholders through educational programs (meetings/field days) to advance onion disease management (Nischwitz/Drost).

Objective 1 (Managing Bacterial Rots). Yearly assessments of commercial farm fields helped us explore bacterial disease presence and management approaches for Utah conditions. At the winter onion meetings, growers signed up to have their fields scouted for disease. Starting in June, fields were assessed weekly for a variety of commonly found diseases. In general, disease pressure each year was low and when diseases were found, they were identified and these findings and management approaches were shared with the participating grower. Then, at the winter onion meetings, an overview of the disease was presented to all Utah growers to educate them on disease pressure. Utah was a participant in the national “Stop the Rot” program. This was part of a major initiative on approaches to managing field and storage bacterial rots. Yearly field trials focused on the use of a range of registered and non-registered materials to manage plant pathogenic bacteria. In these trials even when the fields were inoculated with bacteria, very few symptoms emerge and thus few of the bacterial management options worked to manage the disease. Findings were regularly shared with the onion industry at summer field days and winter meetings (2018-2022).

Objective 2 (Crop Management Approaches): Evaluate onion germplasm for productivity, resistance/tolerance to plant pathogens and insect pests, and identify improved management practices to maintain high productivity. From 2019-2022 we evaluated 60 commercially available cultivars of onions for adaptation to Utah growing conditions. Trials were conducted on cooperating growers' farms and managed according to local practices. Emergence, plant growth, maturity, and productivity were measured. Pest pressure (primarily plant disease) was evaluated throughout the season. Findings were shared with the cooperators, sourcing companies, and the local industry at summer field days and winter meetings each year. Worked with the Irrigation Specialist at USU to evaluate water management practices for furrow and drip irrigated onions in 2018-2020. Using grower farms, fields were instrumented to assess all aspects related to irrigation. Findings showed that in furrow irrigated systems, more water is applied and non-uniform distribution of water causes variable yields throughout the fields. In drip systems, yields are improved but fields are still poorly managed and water use efficiency needs improvement. Fields were assessed for pest pressures (disease) and we generally found that there was no difference between the two irrigation systems for any of the diseases commonly found in Utah production systems (IYSV, neck rot, bacterial bulb rots). From 2020-2021, we gathered seed emergence data to evaluate if emergence variability could predict variable plant growth and productivity (bulb size) in Utah onions through on-farm and targeted research. Findings gathered showed that spring soil conditions (wet/cold) can spread out seedling emergence and that seed priming can improve uniformity. By the fall harvest, differences noted in spring were less evident but primed onion seeds did appear to be uniform in size. We also varied seed density (in-row spacing). As density increased, bulb size decreased as expected and growers now have additional information as they target bulb size to meet market demands.

Objective 3 (Educational Outreach): Each year Utah provided a written and oral report to the W3008 leadership committee to be included in their annual reporting. In addition, topics of interest to Utah onion growers were presented to the Utah Onion Association at its yearly spring (April) board meetings, summer field day (August 2018-2022), and winter educational events (February 2018-2022). Researchers from UUS regularly use the Utah Onion Association board to help direct local research of

importance to the local industry and they help secure funding to support those efforts. Findings from other production regions in the United States provide the context and connect to other onion growers' needs. Findings from other regions also are shared locally by having invited outside speakers which helps further educate the local onion grower community.

Improving Economic and Environmental Sustainability in Tree-Fruit Production Through Changes in Rootstock Use

Project Director

B Black

Organization

Utah State University

Accession Number

1014226



NC140: Improving Economic and Environmental Sustainability in Tree-Fruit Production Through Changes in Rootstock Use

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. To evaluate the influence of rootstocks on temperate-zone fruit tree characteristics grown under varying environments and training systems using sustainable management practices.
3. To investigate physiological processes, biotic and abiotic stresses and scion/rootstock interactions on tree growth and productivity.
4. To integrate and disseminate research-based information that facilitates successful stakeholder adoption of rootstock technologies

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

During the course of this project, 3 to 6 multi-state coordinated rootstock plantings were maintained as part of the NC-140 project, and 3 additional rootstock plantings were maintained as part of the multi-state Root2Fruit project. In addition to these trials, an additional apple rootstock x scion experiment was maintained, and a collection of Navajo peach selections were also evaluated.

Evaluations were made regarding establishment, survival, precocity, productivity, fruit size and quality, alkaline soil tolerance, salt tolerance and root growth patterns.

Results were disseminated in research papers, graduate student theses, and in fact sheets. One fact sheet on alkaline soil tolerance of peach rootstocks has been downloaded 784 times in the 26 months that it has been posted. The graduate student theses have been downloaded a total of 1,435 times, ranging from 60 times for the most recent (April 2022) to 731 for the first published (Jan 2018).

Several of the most significant contributions from this project include the following:

- (1) Root system strength of a series of peach and cherry rootstocks was evaluated after a devastating wind storm. These results will soon be published and are already influencing rootstock selection in commercial orchards.
- (2) The relative alkaline soil tolerance of 17 peach rootstocks was evaluated by comparing growth and leaf chlorophyll levels across three locations with very different soil types. Results have been published both in a scientific journal article and a fact sheet (described above).
- (3) Seedling selections of peach grown by Native American populations in the 4-corners area are genetically distinct from any other known peach germplasm, and have shown superior drought tolerance and an altered root architecture compared to modern rootstock cultivars.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Horticultural researchers, crop consultants, tree fruit nurseries and commercial fruit producers

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

A major windstorm in 2020 completely destroyed one of the apple plantings, primarily due to trellis failure. Two additional rootstock plantings (tart cherry and peach) were also severely impacted. However, for these two plantings the extent of the damage was heavily influenced by genetics. The observed damage has provided very useful information on the relative strength of the rootstocks under evaluation.

Training and Professional Development:

Over the 5 year course of this study, three MS students, 1 PhD student and one undergraduate student inter were trained as part of this project. Two of the three MS students are now county faculty in the USU Extension system. The third MS student is now the Kaysville Farm manager and is overseeing the care of the current NC-140 plantings.

The PhD student is currently completing post doctoral studies at another university. The undergraduate student intern continues to work at the farm while she pursues her education.

Dissemination:

Results of the project were presented to the Utah State Horticulture Association annual winter meeting in all 5 years of the project. This presentation was made virtually in 2020-2022 due to the COVID pandemic. This presentation reached approximately 90 to 120 growers each year representing more than 80% of total fruit acreage in Utah.

Results were also presented at the Northern Utah Fruit meetings in Box Elder County in 2018, 2019 and 2022, with 35 to 50 in attendance at these meetings.

Additional presentations were made at the Utah Water User's Conference (2018, 40 participants), to a small acreage conference at the Wheeler Historic Farm (2019, 26 participants), the Great Lakes Fruit and Vegetable Expo in Michigan (2020, 135 participants), and at the Utah Urban and Small Farms Conference (2021, 205 participants).

The results were also disseminated to the research community through three M.S. theses (2017, 2019 and 2022) and 1 PhD dissertation (2020) that are all publicly available on USU Digital Commons. Further dissemination was through 11 peer-reviewed research papers (4 in 2019, 4 in 2020, and 3 in 2021) with one additional paper currently being revised for resubmission in early 2023.

Publications:

Conference Proceedings:

Minas, I. S., & Black, B. L. (2022). Establishment performance of the 2017 NC-140 semi-dwarf peach rootstock trial across 10 sites in North America. (vol. 1346, pp. 669-676). Acta Horticulturae.

Reighard, G., & Black, B. L. (2022). Thirty-three years evaluating rootstocks for peach in the NC-140: What have we learned. (vol. 1346, pp. 655-660). Acta Horticulturae.

Plan of Work:

Chemical Diversity in Rangelands and Pasturelands: A Sustainable Tool to Enhance Livestock Production and Ecological Health while Minimizing Environmental Impacts

Project Director

Juan Villalba

Organization

Utah State University

Accession Number

1012833



Chemical Diversity in Rangelands and Pasturelands: A Sustainable Tool to Enhance Livestock Production and Ecological Health while Minimizing Environmental Impacts

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The long-term goals of the proposed project are to (i) create an innovative grazing strategy to restore degraded rangelands invaded by medusahead and (ii) assess the ecosystem service improvements of an alternative US beef production system in which livestock are fed and finished on tannin-containing legumes. In order to accomplish these goals, the supporting objectives are:

Objective 1. Investigate a grazing program that provides the appropriate nutrients to enhance utilization of medusahead by cattle.

Objective 2. Use grazing cattle as a tool to help establish perennial grasses and forage kochia, thus creating a positive feedback cycle of grazing-restoration that expands the abundance of nutritious forages across time and space.

Objective 3. Explore the influence of increasingly diverse combinations of tannin-containing legumes on forage intake and production by sheep.

Objective 4. Determine the antiparasitic effects of condensed tannins and how sheep prioritize selection of nutrients and condensed tannins.

Objective 5. Determine in cattle for the finishing phase, intake, animal performance, enteric methane and nitrogen emissions for the tannin-containing legume system compared with “conventional” grass and legume pastures.

Objective 6. Carry out a study on the winter feeding of beef mother cows on legume hay to complete a year-round system on tannin-containing legumes.

Objective 7. Initiate the adaptation of an established cow-calf life cycle assessment to compare environmental impacts of a conventional US beef system or grass-based production system with a tannin-containing legume-based system.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Medusahead is an invasive weed which threatens biodiversity, value of land and livestock operations in rangelands. Utah State University researchers used a combination of treatments that included grazing and herbicide (1-Roundup RT 3®, 2-glyphosate in its potassium salt, 3-glyphosate only) applications as synergistic tools to control this weed. Findings suggest that the integrated approach of glyphosate application and cattle grazing reduces medusahead abundance, despite only small nutritional changes in the vegetation, providing an efficient and sustainable method of medusahead control. In addition, heifers grazing an improved pasture (forage kochia and perennial grasses) and then moved to a medusahead-infested pasture increased intake of medusahead compared to Control (non-supplemented) animals. The use of the herbicide glyphosate increased intake of and preference for medusahead by cattle and sheep. In another study, applications of the herbicide at the

early reproductive stage of medusahead lead to greater levels of preference and intake by cattle, representing a win-win situation for producers since livestock use the weed for forage while “cleaning” and preparing the soil for subsequent seeding during restoration efforts. After removing medusahead through grazing, trampling was found to be a potential tool for establishing perennial species (small burnet) if significant reductions of the seed bank of medusahead was achieved (Objectives 1 and 2). Ruminant livestock production systems are experiencing increasing societal pressures to reduce environmental impacts, while continuing to meet increased production demands profitably enhancing the health and welfare of their animals. Utah State University researchers developed a transformative beef production system based on bioactive (i.e., tannins, saponins)-containing legumes that enhances animal productivity and welfare while reducing environmental impacts. The group tested the effects of increasingly diverse combinations of bioactive-containing legumes (alfalfa [saponins], birdsfoot trefoil and sainfoin [condensed tannins]) on intake and diet digestibility in lambs and heifers. Combinations of bioactive-containing legumes enhanced intake and digestibility of the diet in cattle and sheep, while shifting N losses from urine to feces relative to legume monocultures. Such shift was more pronounced when cattle grazed a combination of different tannin-containing legumes (sainfoin, birdsfoot trefoil), suggesting synergistic effects of the different chemical types of tannins in these legumes. Methane emissions per unit of gain were greater for cattle grazing alfalfa than for cattle grazing combinations of bioactive-containing legumes. Forage diversity did not influence grazing events or other types of activities in cattle like standing, walking, moving or resting, or stress levels (hair cortisol) relative to cattle grazing monocultures of the same species. Thus, spatial segregation of forage species into patches have the potential to enhance animal performance without influencing foraging behavior. The incorporation of a diverse array of chemicals into the diet, like the ingestion of different types and concentrations of condensed tannins or soluble carbohydrates promote synergisms that benefit animal nutrition and health. These findings are significant for livestock producers in the Intermountain West as they suggest improved gains and enhanced efficiencies in animals grazing combinations of “non-traditional” tannin-containing legumes (Objectives 3 and 5). On another study, it was determined how parasitized sheep prioritize selection of crude protein, energy and a medicinal plant secondary compound (quebracho tannins). Results suggest that lambs prioritized the ingestion of energy-dense over protein-dense foods or medicinal condensed tannins when challenged by gastrointestinal parasitism. Consumption of medicinal tannins represented a side-effect of the preference manifested for energy-dense foods during testing (Objective 4). The group also collected critical data on winter feeding beef cows and calves using preserved “non-traditional” forages with bioactive compounds like condensed (sainfoin, birdsfoot trefoil) and hydrolyzable (small burnet) tannins. Results show that tannin-containing hays, as well as other non-traditional tannin-free legumes (e.g. cicer milkvetch), have the potential to reduce environmental impacts relative to alfalfa hay by lowering methane emissions and nitrogen excretion in urine. These results are significant for beef production systems as they suggest that “non-traditional” bioactive-containing hays contribute to a “cleaner” cow-calf phase while maintaining or enhancing levels of animal productivity (Objective 6). Scenarios created in a whole-farm software program (HOLOS) showed tannin-containing legumes have the potential to decrease environmental impact of pasture-finished beef relative to traditional grass- and feedlot-finished beef (Objective 7).

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Livestock producers, extension personnel, land managers, graduate and undergraduate students, conservation agents and professionals, veterinary medicine professionals.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Increased costs of materials/chemicals/salaries due to inflation, put a lot of pressure on the project. It's very difficult to work with a fixed sum of funds/year in a 5 year project.

Training and Professional Development:

This project trained nine undergraduate students (Ian Soufre, Justin Taylor, Gavin Johnson, Raul Lira, Alexis Cooper, Britney Allen, Alyshia Baker, Jacob Poulsen and Jamie Reynolds), student interns from Italy (Alessandro Pira) and France (Pauline Laurent), professors on sabbatical leave from Universidade Rio Grande do Sul, Brazil (Cesar Poli), and from Universidad Autonoma de Morelos, Mexico (Mariana Pedernera). It also trained one recipient of an Undergraduate Research and Creative Opportunities (URCO) Grant (Alexis Cooper), and a professional (MS) intern from San Luis Obispo (Elaina Cromer).

The project trained three MS students (Elizabeth Stewart, Tim Bateman and Raul Guevara Ballesteros), Four PhD students (Sebastian Lagrange, Casey Spackman, Morgane Costes-Thire, and Marina Terra Braga).

Graduate students and visiting scholars were trained in the scientific method, proposal preparation, scientific writing, field data collection and laboratory analyses, near-peer mentoring and opportunities to improve project/personnel management and leadership skills. Undergraduate students were trained in the scientific method, field data collection and laboratory analyses.

Results from Objectives 1-7 were used during lectures in Plant-Herbivore Interactions (WILD 7030) and Range Ruminant Nutrition (WILD 4340/6340) courses (approx. 15 students/year).

I was invited to give presentations with contents of this project at the Universidad of Yucatan, Mexico (2017; approx. 40 students), University of Rio Grande do Sul, Brazil (October, 2017; approx. 30 students), Universidad de Buenos Aires, Argentina (2018/19; approx. 30 students), Universidad de la República, Uruguay (2019; approx. 50 students), Universitat Autonoma de Barcelona (2021; approx. 40 students).

Dissemination:

All the venues described below disseminated information about results related to my UAES project:

<https://extension.usu.edu/rangelands/>

<http://extension.usu.edu/behave/>.

BEHAVE blog. <http://blog.usu.edu/behave/>

<https://www.usu.edu/smart-foodscapes/>

In addition to electronic venues, results are being disseminated by:

Peer-Reviewed Publications

2017: Peer-Reviewed Publications (Total: 8) with Graduate and Undergraduate co-Authors. Invited Synthesis Papers and Book Chapters (Total: 4).

2018: Fact Sheets (Total: 3): With graduate students and Co-PIs of the project. Peer-Reviewed Publications (Total: 8) with Graduate co-Authors and Co-PIs. Synthesis Papers (2).

2019: Peer-Reviewed Publications (Total: 7) with Graduate co-Authors and Co-PIs in the scientific journals. Synthesis Papers (Total: 2).

2020. Peer-Reviewed Publications (Total: 11 during 2020) with Graduate co-Authors and Co-PIs in the scientific journals.

2021/2022: Peer-Reviewed Publications (Total: 13 [4 invited synthesis papers] during 2021) with Graduate co-Authors and Co-PIs in the scientific journals:

Presentations

2017. Invited Presentations (Total: 7): Extensive Livestock Production in the XXI Century (Chile, December 2017), Seminar University of Yucatan, Mexico (Mexico, November, 2017), Livestock State Fair, Yucatan (Mexico, November, 2017), USDA-NIFA Agroecosystems Project Directors Meeting (October, 2017), USDA-NIFA Nutrition, Growth and Lactation Project Directors Meeting (July, 2017), NCERA 214 Sheep Research Meeting (June, 2017), X Latin American Conference of Specialists on Small Ruminant Production (May, 2017). Contributed Student Presentations: The American Society of Animal Science (ASAS) (2 presentations) 70th Annual Meeting of the Society for Range Management (2 presentations).

2018. Invited Presentations (Total: 3): Extensive Livestock Production in the XXI Century (Chile, November 2018), USDA-NIFA Agroecosystems Project Directors Meeting (December, 2018), Platform Speaker for Pastures and Forages (July 2018): 2018 Annual Meetings. The American Society of Animal Science and Canadian Society of Animal Science. Contributed Student and collaborator Presentations: The American Society of Animal Science (ASAS) and Canadian Society of Animal Science (CSAS). 2018 Annual Meeting (5 presentations). 71st Annual Meeting of the Society for Range Management (3 presentations).

2019. Invited Presentations (Total: 5): 1-Meeting on the Biology of Behavior in South America (Keynote Speaker; Uruguay, November, 2019), 2-Group Meeting on Sustainability (Uruguay, 2019), 3-Workshop-Extensive Livestock Production in the XXI Century (Chile, November 2019), 4-Field Day-Extensive Livestock Production in the XXI Century (Chile, November 2019), 5-Lecture, University of Utah (September 2019). Contributed Presentations by Students and Visiting Scientists under my supervision: The American Society of Animal Science (ASAS) and Canadian Society of Animal Science (CSAS) (2 presentations). Annual Meetings of the Society for Range Management. Undergraduate Research Symposium.

2020/2021. Invited Presentations (6). 1-USU Forestry Chapter. Intermountain SAF Virtual Conference. Climate Change, Management, and Policies. April 23, 2021. 2- Extensive Livestock Production in the XXI Century. Interpretation and project implications. Punta Arenas, Chile. Virtual meeting. June 24, 2021. 3-Ingestive behavior in sheep in relation to body weight gains. 3rd International Conferences FESC-UNAM on Ovine Production. Autonomous University of Mexico (UNAM), Cuautitlán, Mexico. Virtual meeting, May 26, 2021. 4-The Joint XXIV International Grassland and XI International Rangeland Congress. Virtual meeting. 25-29 October, 2021. 5-International Workshop: Grazing in Future Multiscapes: From thoughts to landscapes, creating health from the ground up. Lincoln University. Centre of Excellence. Designing Future Productive Landscapes. Virtual meetings. June-July, 2021. 6- American Society. 6-The American Society of Animal Science (ASAS) and Canadian Society of Animal Science (CSAS), Oklahoma City, Oklahoma, June 26,30, 2022. Contributed Presentations by Students and Visiting Scientists under my supervision: The American Society of Animal Science (ASAS) and the Canadian Society of Animal Science (CSAS) Joint Annual Meeting. Louisville, KY. July 14-17, 2021.Tri-Society Virtual Conference July 5-9, 2021.

Plan of Work:

This is the FINAL report.

A new project started in 2022.

Employing Forage Legumes to Improve the Sustainability of Ruminant Production

Project Director

Jennifer MacAdam

Organization

Utah State University

Accession Number

1012899



Employing Forage Legumes to Improve the Sustainability of Ruminant Production

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The goal of this project is to explore the composition and influence of irrigated perennial legumes, with and without tannins, on ruminant production, and impacts on the environment compared with ruminant production on irrigated grass or in feedlots.

This will be addressed under three objectives:

1. Determine the effect of perennial legume fiber-carbohydrate-tannin-protein dynamics on ruminant productivity, compared with ruminants on grasses.
2. Determine the long-term impact of nitrogen-fixing perennial legume pastures on soil carbon and nitrogen dynamics, compared with nitrogen-fertilized grass pastures.
3. Determine the effect of perennial legume tannin-ruminant-soil nitrogen cycling on soil organic matter and carbon sequestration.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Three studies were carried out as part of this Utah Agricultural Experiment Station project.

A study was carried out under irrigation comparing the forage production and nutritive value as well as the intake and enteric methane emissions of dry cows, pregnant cows, yearling calves, and 2-year-old heifers on irrigated pastures. The treatments included two non-bloating monoculture legume (birdsfoot trefoil and cicer milkvetch) pastures and a monoculture meadow brome grass pasture. A total mixed ration treatment was included in the final two years of the study. This project demonstrated that enteric methane as a function of intake was significantly (40%) less on monoculture legume pastures than on

monoculture meadow brome grass pasture for all the tested classes of cattle. It also demonstrated that methane emissions did not differ when 2-year-old heifers grazed legume pastures or were fed a total mixed ration in confinement. Most irrigated pastures in the northern Mountain West are dominated by grasses, and this series of studies demonstrated that cattle enteric methane emissions could be greatly reduced by substituting non-bloating legumes for grasses in irrigated pastures.

A dryland study of six sainfoin cultivars was planted in the early autumn of 2018 and sampled at the 10, 50, and 100% bloom stage for two years, in 2019 and 2020, and at the 100% bloom and one month post-bloom stage for two years, in 2021 and 2022. The yield of these cultivars was greatest in the first year after planting, ranging between 5.29 (Shoshone) and 7.63 (Remont) Mg/ha, and decreasing to between 2.21 (Delaney) and 4.30 (Shoshone) Mg/ha by the third year after planting. Forage quality did not decrease significantly over the four years of the study, or as sainfoin matured from 10 to 100% bloom; blooms mature quickly and stems are fully elongated when flowering begins. Tannin concentration was similar for all cultivars and in the range of 4% of dry matter although it varied with precipitation. At one month after full bloom, seed pods were maturing and protein concentration of sainfoin had decreased from 18.60% at full bloom to 8.95%. However, energy concentration measured as non-fiber carbohydrate concentration was still high: 47% at full bloom and 40% at one month post-bloom. Digestibility decreased from 82% at full bloom to 69% at one month post-bloom, and total digestible nutrients (TDN) decreased from 71% at full bloom to 57% at one month post-bloom. These results demonstrate that sainfoin is a high-protein and extremely high-energy forage at maturity, and that it retains nutritive value with maturation even under dryland conditions.

An irrigated study of a reduced-lignin alfalfa and meadow bromegrass was planted in the early fall of 2019 and has been sampled at 2-week intervals during the growing season for the subsequent 3 years, primarily to document the development of non-fiber carbohydrate (NFC) concentrations. The concentration of NFC is greater, at nearly 40%, than is found in alfalfa at lower-altitude locations (e.g., NFC is 25% in alfalfa grown at Fresno, CA). The NFC of alfalfa decreases as the crop matures from the vegetative to the full bloom stage over the course of three cuttings, and is greater in spring and late summer than in mid-summer, but remains between about 35 and 45%. The reduced-lignin trait does not appear to increase the NFC of alfalfa. The increased accumulation of NFC in northern Mountain West locations greater than 4000 ft. in elevation may be due to elevated solar radiation, and is likely due to greater soluble fiber concentrations in alfalfa stems. Alfalfa is a high-protein source of fiber, especially valued in dairy rations, and high-forage diets are beneficial for dairy cattle. If the NFC concentration of Mountain West-grown alfalfa were calculated and factored into dairy rations, the concentration of alfalfa could be significantly increased (e.g., from 25 to 45%), reducing feed costs for dairy producers while not altering dietary NFC or reducing expected milk production.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

The benefit to the public from the study comparing different classes of beef cattle grazing legume pastures vs cattle grazing grass pastures or fed a total mixed ration (TMR) is that cattle grazing legume pastures emitted no more methane than cattle fed a TMR but much less methane than cattle grazing a high-quality grass pasture. Grazing legume pastures is a lower cost feed than a TMR diet and results in a more favorable omega-6 to omega-3 fatty acid balance in the meat but is as well-liked as grain-finished beef (found in earlier research).

The study of sainfoin cultivars demonstrated that sainfoin could be highly productive in dense stands under dryland conditions. These results provided valuable preliminary data for the current NIFA-funded grant "Using Smart Foodscapes to Enhance the Sustainability of Western Rangelands" which in turn is using sainfoin as the key plant species in resource islands that will be used to supplement pregnant cows in late summer and early autumn. This standing supplementation will replace hay or protein cakes that are more costly for ranchers. Beef production is the major agricultural pursuit in rural Utah, so this project has the potential to benefit individual ranchers and the communities where they live.

The study of non-fiber carbohydrates in alfalfa, which were found to constitute about 40% of the dry matter in this and other studies, could increase the proportion of dairy cow rations from about 25% to 45%, significantly reducing the cost of dairy rations and increasing the health of dairy cattle consuming Mountain West hay. The benefit to producers would be reduced

feed costs and more lactations per cow, the benefit to hay producers would be higher revenues for no additional input costs, and the benefit to the public would be a more secure local supply of high-quality dairy products and more prosperous rural communities.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems: No significant problems were encountered, and no changes were required.

Training and Professional Development:

The studies that were carried out as part of this UAES project have been used as part of the training for one PhD student, Andrea Bolletta, and one master's student, Raul Guevara. In addition, 10 undergraduate students have been mentored in the PD's lab, as well as one SURE intern.

Dissemination:

The PD has presented results of the research carried out as part of this project at the Crop Science Society of America annual meetings and at annual meetings of the multistate committees NCCC-31 and WERA-1014. The PD has also participated in field days organized by Utah Cooperative Extension, taking the opportunity to explain the basis for the research and its implications for the benefit of Utah and western agricultural producers.

Products/Publications:

Pitcher, L. R., MacAdam, J. W., Ward, R. E., Han, K.-J., Griggs, T. C., & Dai, X. (2022). Beef steer performance on irrigated monoculture legume pastures compared with grass- and concentrate-fed steers. *Agronomy*, 12:1017.

Other:

Bolletta, A., Villalba, J., Dai, X., & MacAdam, J. W. (2018). In vitro digestibility and fermentation kinetics of six irrigated forage hays in the US Intermountain West. *Journal of Animal Science*, Suppl. 3, 96: 218-219.

Cherney, J.H., Albrecht, K.A., Berti, M.T., Bohle, M., Bosworth, S.C., Cassida, K.A., Cox, W.J., Creech, J. E., Fransen, S.C., Hall, M.H., Hannaway, D.B., Islam, M.A., Johnson, K.D., MacAdam, J. W., Meccage, E.C., Putnam, D.H., Rayburn, E.B., Sheaffer, C.C., Shewmaker, G., Solomon, J., Sulc, R.M., & Volenec, J.J. (2018). Forage crops need respect. *Hay and Forage Grower*, 33, 18-19.

Cherney, J.H., Albrecht, K.A., Berti, M.T., Bohle, M., Bosworth, S.C., Cassida, K.A., Cox, W.J., Creech, J. E., Fransen, S.C., Hall, M.H., Hannaway, D.B., Islam, M.A., Johnson, K.D., MacAdam, J. W., Meccage, E.C., Putnam, D.H., Rayburn, E.B., Sheaffer, C.C., Shewmaker, G., Solomon, J., Sulc, R.M., & Volenec, J.J. (2018). Forage in crisis: Forage crops don't get no respect. *Progressive Forage*, September, pp.14-16.

Hemken, M. (2019). Rethink Pastures to Boost Stocking Rates. In Jennifer W. MacAdam (Ed.), *Western Farmer-Stockman*.

Lagrange, S., Guevara Ballesteros, R., Beauchemin, K., MacAdam, J. W., & Villalba, J. (2018). Methane emissions by cattle grazing tannin-containing legumes. *Journal of Animal Science* Suppl. 3, 96: 223-224.

Lagrange, S., Beauchemin, K. A., MacAdam, J. W., & Villalba, J. (2017). Effects of grazing diverse combinations of sainfoin, birdsfoot trefoil and alfalfa on beef cow performance and environmental impacts. *Journal of Animal Science*, 95:143-144.

Leggett, K., McCann, R. B., MacAdam, J. W., & Villalba, J. (2018). Rocky Mountain Trefoil Beef. (sustainability/2018/01pr ed.). Utah State University.

MacAdam, J. W. Effect of Oven- Vs. Freeze-Drying on the Condensed Tannin Concentrations of Sainfoin and Birdsfoot Trefoil. Madison, WI: Annual Meetings Abstracts. ASA, CSSA, and SSSA,.

MacAdam, J. W., & Yost, M. (2020). Mountain Hay. *Progressive Forage*, Issue 2, February 1, 2020.

MacAdam, J. W. (2019). The elevated carbohydrate concentrations of high altitude-grown perennial legume forages. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.

MacAdam, J. W. (2018). Legume-finished beef. *Hay and Forage Grower*, April-May, pp. 30-31.

MacAdam, J. W., Cassida, K. A., & van Santen, E. (2017). Location of growth influenced birdsfoot trefoil tannin accumulation, but few accessions differed in tannin concentration. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI..

Roca-Fernandez, A. I., Dillard, S. L., Dell, C. J., MacAdam, J. W., & Soder, K. J. (2017). Effect of oilseed source on ruminal fermentation and methane production of a grass-legume diet in continuous culture. *Journal of Animal Science*, 95: 133-134.

Roca-Fernández, A. I., Dillard, S. L., Rubano, M. D., Baldin, M., Dell, C. J., MacAdam, J. W., & Soder, K. J. (2017). Modification of ruminal fermentation and methane production by adding legumes containing condensed tannins to an orchardgrass diet in continuous culture. Abstract, American Dairy Science Association Annual Meeting, June 25-28, 2017, Pittsburgh, PA.

Stewart, E., MacAdam, J. W., & Villalba, J. (2018). Alternative Legume Species Can Reduce the Environmental Impacts of Cattle. (AG/Forage/2018-02pr ed.). Utah State University.

Stewart, E. K., Beauchemin, K. A., MacAdam, J. W., & Villalba, J. (2017). Environmental impacts from cattle consuming tannin-containing hays. *Journal of Animal Science*, 95:133-134.

Tracy, B.F., Albrecht, K., Flores, J., Hall, M., Islam, A., Jones, G., Lamp, W., MacAdam, J. W., Skinner, H., & Teutsch, C. (2018). Evaluating grass-legume mixtures across different environments. *Crops and Soils*, 51: 30-34 & 47.

Villalba, J., Beauchemin, K., & MacAdam, J. W. (2018). Nutrients and plant secondary compounds in pasturelands and their ecological services. *Journal of Animal Science*, Suppl. 3, 96: 211.

Zhang, Y., & MacAdam, J. W. (2018). In vitro rumen fermentation of six pasture species and their isolated fiber. In Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI..

Other Products

Data and Research Materials Fatty acid and rumen microbiome data from cattle on feedlot, grass and legume diets were generated and interpreted in 2020. Stands of alfalfa and meadow brome grass established in fall of 2019 were sampled biweekly to determine the concentration of non-fiber carbohydrates and other forage nutritive value characteristics along with dry matter production. A second year of yield, forage quality and tannin concentration was determined in a dryland study of six sainfoin cultivars.

Audio or Video - As part of a thesis, a graduate student produced a video demonstrating the elements of extension videos needed to increase their accessibility to the d/Deaf and hard-of-hearing communities along with a video to exemplify a d/Deaf and hard-of-hearing extension video.

Data and Research Materials Samples of rumen fluid, blood and subcutaneous fat were collected from cattle in late May, before animals were subjected to diet treatments. Cattle were sorted by weight and distributed among four treatments: grass pastures, pastures of a tannin-containing legume, pastures of a non-tannin legume, and a feedlot treatment. On the day that cattle were removed from the pasture at the end of the grazing season, in late August, the same sampling was done. These samples will be analyzed for fatty acid composition, and the rumen fluid samples will be assayed to determine differences in the microbiome resulting from treatments.

Data and Research Materials Data from a field study were used to compare enteric methane emissions and urine and feces nitrogen of beef cattle on four treatments: irrigated non-tannin legume (cicer milkvetch) pastures, irrigated tannin-containing pastures (birdsfoot trefoil), irrigated grass (meadow brome) pastures and a feedlot. 2018 was the second year of this two-year study. The intake and digestibility of the forages grazed by these cattle will be determined from pre- and post-grazing pasture dry matter and chromic oxide dosing. Data were also collected on soil nitrogen form and concentration (ammonium and nitrate) before and after grazing, and on fatty acids in the rumen fluid, blood and subcutaneous fat of cattle before and immediately after 12 weeks of grazing.

Data and Research Materials Data were collected in 2017 on enteric methane emissions of cattle on legume and grass pastures, as well as the nitrogen concentrations of the urine and feces of these cattle. The intake and digestibility of the forages grazed by these cattle will be determined from pasture sampling and chromic oxide dosing. Data were also collected on soil nitrogen form (ammonium and nitrate), and rumen fluid and blood samples will be analyzed for fatty acid concentrations.

Plan of Work:

None, this is the FINAL report



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The long-term goal of the proposed project is to employ the phenomenon of CRISPR/Cas9 genome editing to improve the efficiency of knock-in for the production of genetically engineered livestock for agriculture and biomedical research. The specific objectives are to: 1) Optimize efficiency of Knock-Ins using CRISPR/Cas9 and chemicals (NHEJ inhibitor and HDR enhancer), 2) Assess effectiveness of Cas9 nickase for KIs in sheep and goat fetal fibroblasts, 3) Develop a safe-harbor ROSA26 KI method, 4) Evaluate efficiency of a novel NHEJ-based method for KIs, and 5) Generate and characterize genetically modified goats and sheep using CRISPR/Cas9 mediated KIs.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

This project was focused on utilizing new approaches to improve efficiency of gene editing in livestock. During first year, we worked on introduction of mutations (indels) by NHEJ approach in the ovine Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) gene. We were able successfully produce CFTR-null cells (Ex 11 and Ex 2). We also attempted to introduce targeted mutations (KIs) using various single-stranded oligonucleotides (ssODN) flanking the CRISPR/Cas9 target located within the exon 11 of the CFTR gene. The ssODN with 40, 60, 90, and 115 bp were designed based on Renaud and collaborators (2016) approach. However, no KIs have been accomplished in these experiments. It is possible that when the CRISPR/Cas9 plasmid (px330) is used, the timing between synthesis of the protein and guide RNA, and action of the CRISPR to perform the DSB is out of sync. Therefore, we evaluated CRISPR/Cas9 ribonucleoprotein (RNP) delivery in addition to the CRISPR/Cas9 plasmid approach. Using this method (CRISPR/Cas9 RNP), we were able to achieve >99% efficiency of KO of the Rosa26 in sheep fetal fibroblasts (SFFs). Additionally, we have developed a GFP-Neo donor reported vector for goat Rosa 26 gene that will be used to optimize KI efficiency.

Year 2, we introduced the F508del and G542X human mutations into the CFTR gene in SFFs using CRISPR/Cas9 RNP. The F508del mutation is the most common mutation in the human gene characterized by the deletion of the 'CTT' nucleotides and ultimately the Phenylalanine residue at the position 508. The G542X mutation is a common "stop" mutation in the human gene that causes loss of functional CFTR protein. We used CRISPR/Cas9 for these mutations' introduction into the sheep genome. We designed gRNA targeting exon 11 (F508del) and exon 12 (G542X) using the Benchling software. Cas9/sgRNA RNP complex was transfected into SFFs along with 100 bp ssODN carrying the F508del or G542X mutations. 56 colonies were isolated by limited dilution and screened for introduction of F508del mutation. The results showed that the indels were introduced in 49/56 (87.5%) colonies, and four (7.14%) of them had biallelic F508del mutations. For the G542X, mutation efficiency was 70% based on PCR-RFLP assays. Nine of 23 colonies (39%) were confirmed to have biallelic G542X mutations. Furthermore, these cells were used for SCNT and transferred to 7 recipient ewes (4 with G542X and 3 with F508del embryos). Pregnancies were confirmed by ultrasonography around D40 of gestation. The initial pregnancy rate was 75% (3/4) for the G542X and 33% (1/3) for the F508X mutations. In Y2 we were successful in developing an efficient protocol for the introduction of human specific mutations into the sheep genome.

Additionally, in Y2 we generated NANOS2 KO goats using CRISPR/Cas9 and SCNT. The NANOS2 gene, encoding an RNA binding protein, is known to play a critical role in the development of germline for all organisms studied to date. The targeting vectors were constructed using the px330 plasmid and transfected into goat fibroblasts. Three male and two female colonies with NANOS2 null mutations were identified and used for SCNT. Totally, 202 cloned embryos were generated and surgically transferred into 12 estrus synchronized recipients. Five pregnancies developed to term, resulting in 6 kids (5 males and 1 female). PCR/RFLP assays and sequence analysis showed that both male and female offspring carried the mutations in NANOS2. Histological evaluation of testis of NANOS2-/- males clearly confirmed that they are germline ablated.

Year 3, we tested the effects of the DNA-dependent protein kinase inhibitor M3814 on CRISPR-mediated genome editing in

ovine-bovine interspecies embryos. We utilized embryos generated by ovine-bovine interspecies somatic cell nuclear transfer (iSCNT) due to a limited access to sheep oocytes. These iSCNT embryos carried a CFTR/G542X mutation, which we attempted to correct by cytoplasmic injection of a Cas9/gRNA RNP complex together with a single-stranded oligodeoxynucleotide (ssODN). Sheep fetal fibroblasts containing homozygous G542X mutations (the first nucleotide 'G' at G542 site of CFTR was replaced by a 'T', resulting in the formation of a stop codon 'TGA') were used for iSCNT. Based on the sequencing results, a gRNA and a ssODN were designed and used to correct the G542X mutation in the iSCNT embryos. Cas9/gRNA and ssODN compound were injected into 1-cell stage embryos 4 hrs post-activation using a Piezo system. The injected embryos were cultured either in SOF medium (control) or SOF medium supplemented with 2 μ M of M3814. The sequencing results performed 3 days post injection showed that no correction was observed (0/8) in the control group; however, 2 out of 8 embryos (2/8, 25%) in the experimental group were partially corrected. One embryo contained a heterozygous correction, and the other was mosaic. Due to small number of iSCNT embryos produced for mutation analysis, we could not draw a conclusion if M3814 enhances CRISPR-mediated genome editing in iSCNT embryos, though the preliminary results look promising. In Y3, we also used F508del and G542X CF fibroblasts as nuclear donors for SCNT to produce F508del and G542X CF lambs. Totally, we produced four lambs, two for each mutation. The lambs exhibited similar pathophysiology to CFTR-null sheep.

Year 4-5, we work on generation of a new Sickle Cell Disease (SCD) sheep model. SCD is caused by a single 'A to T' nucleotide replacement at the sixth codon of the β -globin (HBB) gene, which results in the substitution of valine for glutamate in the β -globin protein at that position. In sheep, fetal HBB (fHBB) and adult HBB (aHBB) genes contain many homologous sequences including the site of SCD causing mutation. Thus, we designed a target sequence (converted into gRNA) using the Benchling software that could target both genes simultaneously. ssODN homologous to the *aHBB* gene carrying the SCD mutation (ssODN_1), and ssODN with homologous arms to the *fHBB* gene containing a silent mutation (ssODN_2) were also designed. The ssODN_1 was designed to replace the 'A to T' nucleotide at the 6th codon of the aHBB gene. The ssODN_2 was designed to carry a silent mutation in the 8th codon to protect the *fHBB* gene from being disrupted by the action of CRISPR/Cas9. Prior to the transfection, 3 μ l of 100 μ M gRNA was incubated with 2 μ l of 5 μ g/ μ l Cas9 protein for 10 min at room temperature to form an RNP complex. The RNP was then incubated with 2ml of 200 μ M of each ssODN for 5 min and transfected into 2.8x10⁶ SFFs in a 100 μ l Nucleovette system. Single cell colonies were subjected to PCR-RFLP testing and Sanger sequencing. The sequencing results from both fHBB and aHBB genes indicated that we obtained 2 colonies contained SCD biallelic mutations and KI mutations. The colonies were cryopreserved and successfully used for cloning in Y5 of this project.

Optimization of Point-Mutation Introduction Using Three ssODN Sizes. We compared efficiency of three sizes of homologous arms (HA) (60, 100, and 127 nts) to introduce point-mutations. The oligos were designed to introduce a single nucleotide change in the exon 12 of the CFTR gene (GGA to AGA), a common site for mutation in human Cystic Fibrosis patients. Using CRISPR/Cas9 RNP, we transfected three groups of fibroblasts with CRISPR/Cas9 along with 400 μ M of ssODNs using an electroporation method. Three days after transfections, the DNA was extracted and exon 12 was amplified by PCR. PCR-RFLP analysis indicated that the knock-in efficiency was around 16% $\pm$ 2 for each of them, thus, demonstrating that no improvements were observed using longer HAs and a small 60 nt ssODN can be as effective as a longer 127 nt.

In summary, using ssODN along with CRISPR/Cas9 RNP in a single round of transfection, we can successfully introduce biallelic SCD and CF (F508del and G542X) mutations in sheep.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

Numerous poster and oral presentations (related to this project) were given during the last 5 years. Here are some of the examples: poster and oral presentations at annual conferences of the International Embryo Technology Society (Jan 2018-Jan 2022); oral presentations at the W3171/W4171 multistate project meetings (2018-2022); an invited oral presentation at the University of Connecticut (2021), poster and oral presentations at the Cystic Fibrosis Foundation research meetings (2019, 2021, 2022), oral presentations at the PAG conferences (2019, 2020), an invited oral presentation at the 54th Society for the Study of Reproduction annual meeting in St Louis, MO (2021) and an invited oral presentation at the ASGCT (May, 2022). We have also presented our research data at the International Workshop on LIVESTOCK GENE EDITING TANUVAS, Chennai, India, August, 2019 and at the Large Animal Genetic Engineering (LAGE) Summits organized by USU in 2018 and 2022.

Dissemination:

The results of this project were presented at several international and national meetings listed above. The data were also published. In 2021, we published two review papers: the first Perisse et al. "Improvements in Gene Editing Technology Boost Its Applications in Livestock" (Frontiers in Genetics) and the second Polejaeva "Generation of genetically engineered livestock using somatic cell nuclear transfer" was part of an anniversary issue on the 25th Anniversary of cloning by somatic cell nuclear transfer published by Reproduction. We also published a research paper (Perisse et al., "Sheep models of F508del and G542X cystic fibrosis mutations show cellular responses to human therapeutics" in Aug 2021 in FASEB BioAdvances).

Plan of Work:

This is our Final Report.

Mitigating the bioavailability of toxic trace elements through monitored natural attenuation

Project Director

P Grossl

Organization

Utah State University

Accession Number

1012950



Mitigating the bioavailability of toxic trace elements through monitored natural attenuation

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The overall objective of the proposed research is to determine the processes regulating the bioavailability of potentially toxic trace elements, and through natural attenuation monitoring find the best management practices that will mitigate their threat to the environment. The study will focus on the biogeochemistry of selenium and lead. Specific objectives are:

- 1) Evaluate the sorption chemistry of the trace elements Se and Pb in regional soil environments so as to better understand the processes controlling their bioavailability. This will involve sequential extract procedures (SEP), and sorption studies.
- 2) To determine the constituents (soil organic matter, clays, carbonates, and oxides) and conditions (pH and organic matter content) that, provide maximum sorption (minimum bioavailability) of Se and Pb. These studies will involve field and greenhouse bioassays.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Research interests in Se contamination and phosphate mining have greatly expanded, due to the exceedingly high levels of bioavailable Se found in semi-arid soils of the Western Phosphate Resource Area (WPRA). This has resulted in acute Se toxicity and fatalities in livestock and wildlife throughout the region due to grazing on hyperaccumulating vegetation, particularly western aster (*Symphyotrichum ascendens* (Lindl.)). Selenium bioavailability to vegetation is controlled by its behavior in soil systems related to pH, oxidation reduction potential, mineralogy, organic matter, and the presence of competing anions. Effective methods for Se remediation are imperative with looming threats of additional livestock fatalities from grazing. We evaluated strategies, more applicable to sites within the

WPRA, that would decrease Se mobilization and result in lower Se accumulation in western aster and consequently lower the threat to grazing livestock. Appropriate remediation strategies that can be implemented throughout the WPRA and similar sites were developed and tested in the greenhouse. One promising method that still needs to be field tested is the use of zero valent iron for reductive stabilization.

Organic carbon treatments are a helpful reclamation soil health tool that can improve soil structure, increase microbial biomass, increase water retention, alter soil nutrient content, absorb harmful soil contaminants, as well as a method of carbon sequestration. However, carbon additions do not address the saline and sodic soil issue. We tested various types of carbon treatments (activated carbon, biochar, compost, Desilt Pond dredge material, and woodchips). The treatments were incorporated into the soil at a rate of 2% carbon. Wood chips and, to some extent, biochar was able to hold more soil moisture than non-treated controls.

Sodic soils (SAR above 13) have a higher soluble sodium ion than calcium ion concentration thus causing the soil to disperse as indicated by cracking and crusting at the surface of the soil.

Traditional reclamation of sodic soils is done by adding gypsum as a source of exchangeable calcium. This method of reclamation does not work in gypsiferous rich soils that are common throughout the Uintah Basin. The addition of gypsum will increase the issue with sodicity by plugging the soil pores with precipitated gypsum. The recommended best practice for the Uintah Basin is to decrease the soil pH by adding elemental sulfur. Water is the limiting factor of this treatment. However, once the sulfur is wet, it will convert into sulfuric acid thereby lowering the soil pH. The lower pH causes calcium to go into the solution, and once the calcium ions are greater than the sodium ions in the solution, the soil will flocculate by opening pore space allowing water to infiltrate and be available for plants to uptake. Electromagnetic Induction (EMI) sensing is a tool that can be used to target reclamation on P&S well pads. The benefit of EMI is to provide a cost-effective way of targeting just the saline or sodic soils, therefore, saving companies money. EMI correlation to soil health did not provide better information better than a traditional soil test.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems: Nothing to report.

Training and Professional Development:

We have been involved in workshops on soil reclamation and soil health for the BLM Field Office and Oil Company reclamation specialists.

Dissemination:

We have hosted several annual soil reclamation workshops to disseminate information from these studies to industry and agency reclamation specialists and land managers. Our local soil analysis lab assists with identifying soil health issues associated with reclamation and it continues to expand and grow based on industrial needs. One review article was published in *Chemosphere*, a peer reviewed high impact scientific journal. Five journal articles were published in high impact scientific journals.

Plan of Work: This is the FINAL report



Production and Economic Factors Associated with Automatic Milking and Feeding systems (Robotic) Dairies Under Western U.S. Conditions

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. To develop baseline levels for production variables and their value to determining health, production and economics.
2. To determine the precision of the automated milking systems (AMS) technologies.
3. To determine the relationship between AMS pellet composition and ration composition based on the quality of alfalfa fed under western U.S. conditions.
4. To disseminate the information to the dairy industry of the western U.S.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

For Objective 1:

a. I have compiling data files for individual cow data and for robot-level data. The main dataset has approximately 107,470 lines of data starting from July 1, 2018 to the end of October 2019. It is composed of daily production averages for each cow on the dairy. The daily robot summary information of production values beginning on June 10, 2018 to the end of October 2019 for a total of over 1,000 daily summaries for the two robots.

b. One thing that is not available from any of the reports available from the robots are the ability to look at production based on days in milk (DIM). The biggest surprise was that a significant change occurred for the Jersey cows around 28 to 31 DIM. For reasons that are unknown, at 28 DIM, milk production decreased over a 2 to 3-day period by 7.5 lb (3.4 kg), the amount of pellets received by those cows decreased by 1.1 lb (0.5 kg) and 2 days later, milkings per day decreased by 1.1 milking. Interestingly, the average refusals per cow, spiked on the day that the milkings/day decreased and slowly decreased to baseline about 4 days after the event. Refusals are when a cow comes into the robot, but enough time has not elapsed for her to be milked. This suggests that the changes in production were not because the cows didn't want to be milked; their desire to be milked was reflected by the spike in refusals. Milk production decreased at a linear rate from that point to approximately 150 DIM. Body weight (BW) was analyzed and percent change in relation to the initial body weight was calculated by DIM. The Jersey cows lost about 3.5% of BW until 30 DIM, then when milk production and the pellet abruptly decreased, they lost another 3% BW and stayed at this level until 150 DIM when the computer automatically decreased the pellet and they lost another 6% BW. The BW did not return to the initial weight until approximately 226 DIM. As a contrast, the Holsteins lost about 6% BW until 27 DIM and returned to their initial BW by 45 DIM. In addition, the Holstein milk production increased, as would be expected, until 45 DIM, then increased a little more after they had returned to their original weight. There was not a decrease in the amount of pellet received as was seen at 28 DIM for the Jersey.

My conclusions for these differences are: a) there is an unexplained change in the computer software for the Jersey robot that is causing that unexpected decrease at 28 to 30 DIM; and b) the ration for the Jersey cows are being underfed energy, which is causing a slow return to their original body weight.

c. The robot-level data for the Holstein cows showed that within the range of 51 to 68 cows/day, there was a linear increase in percent of time during the day that the robot was milking, milkings per day decreased at a linear rate from 2.9 to 2.4 and milk per cow per day decreased until the number of cows reached about 58. Average milk per cow was linearly associated with increased amount of pellet received per cow, as would be expected. For the Jersey-only robot, within the range of 49 to 58 cow per day, there was an increase in milkings per cow per day as more cows were added to the robot. The percent of time that the robot was used during the day also increased as more cows were added but showed signs of leveling off at about

72%. Total milk produced by the robot per day leveled off at approximately 55 to 56 cows. These results may have been because of the number of refusals per cow per day. The average refusals for the Holsteins was less than 1 time per cow per day. The average for the Jersey cows was between 5.0 and 5.5. At 58 cows, it jumped to 7. These are very high numbers.

The feed table is what the robot uses to determine how much extra pellets should be fed to a cow, based on individual production. The robot has a separate table for Holstein cows and Jersey cows and is based on the manufacturer's experience. Regression analysis of milk production compared with pellet allotment was conducted for both the Holstein and Jersey cows separately. It was concluded that the feed table for the Jersey cows needs further research and refinement because the allotment seemed to not adequately support high producing Jersey cows.

My conclusions are that while it may seem intuitive that Holsteins and Jerseys are different, most AMS systems tend to treat them similar. Data to this point suggests they should be treated different, but there is little information to make recommendations on how to manage them.

d. A study was conducted to investigate the effects of including novel alfalfa products: ProLEAF MAX™ (PLM), an alfalfa leaf pellet; and ProFiber Plus™ (PFP), alfalfa stems, in the ration of lactating dairy cows on DMI, milk yield, milk components, body weight, rumination, and somatic cell count. The data indicated that inclusion of fractionated alfalfa products in the ration of lactating dairy cows has the potential to increase milk yield and milk components and, therefore, may increase profitability.

My conclusion is that even though it is hard to conduct traditional research using robots because of the lack of individual feed intakes, the amount of data that is available can provide meaningful results and overcome some of the limitations. This research has been summarized and is close to being submitted for publication (Objective 4).

e. Many dairies in the Intermountain area have converted to AMS with a variety of different types of facilities constructed to house the robots. A partial budgeting framework was used to calculate the net financial impact associated with the AMS system and the barn to house the system. This framework was modified from the partial budget of Bentley et al. (2018).

Scenario 1 represents a minimal retrofit to existing facilities with cost of the facility retrofitting at \$70,000. *Scenario 2* involves the construction of a new open-sided barn at a cost of \$470,000. For *scenario 3* a new fully enclosed barn was constructed at a cost of \$920,000. The initial capital outlay obviously changes across the three scenarios, but perhaps less intuitive, milk productivity, feed efficiency, and labor savings also vary across the scenarios.

Using the assumptions, we calculated the static net annual financial impact as well as the total change to cash flow under the three investment scenarios. We concluded that scenario three had the largest positive increase in net financial impact and cash flow was least negatively impacted. It would appear that the fully enclosed barn had the potential for the greatest net annual income and would be the most desirable investment strategy. However, scenario 3 has the greatest risk of all scenarios (variability, range, and % of values < \$0). In short, scenario 3 requires the largest financial investment, but has the potential of the greatest gains. Some producers may be unwilling or unable to make this large of an investment. All three scenarios are likely viable for individual producers with different risk tolerances and financial positions.

The results of the analysis indicate that we would expect all three scenarios to have a positive annual financial impact. However, this positive financial impact must be considered together with the projected total annual change in cash flow. Before any producer makes the switch to AMS, consideration must be given as to whether the farm has the ability to absorb the projected negative impact to cash flow until the loans can be paid down.

For Objective 2, individual milk samples were collected using the Lely Shuttle. Samples were taken to Rocky Mountain DHIA and analyzed for fat%, protein%, and somatic cell count. This was done on 3 different occasions, resulting in almost 300 samples. The RMDHIA laboratory results are considered the 'gold standard'. Analysis of the results showed a low correlation for individual cows but were similar on a herd basis. Further work by the manufacturer needs to be done to increase the accuracy.

Briefly describe how your target audience benefited from your project's activities.

Target audience are dairy farmers, support ag industry companies and the public.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems: None, This is the FINAL report.

Training and Professional Development:

- a. Attended symposium at the American Dairy Science Association annual meetings on updates in robotic use and research.
- b. Attended Lely Robot Liner Evaluation Training (2-day)
- c. Attended presentations and a symposium at the American Dairy Science Association annual meetings on research in robotic use.
- d. Attended on-line research and extension webinars on how to evaluate automatic milking systems.

Dissemination:

I gave a tour of the USU robotic dairy for:

- a. the BUILD dairy program (university students and allied personnel from western U.S.; video tour)
- b. an elementary class from Herriman, UT (set up through Dairy West; dairy promotion group for Utah and Idaho; video tour).
- c. USU Open House (I gave information on records collected by a robot).
- d. Delegates from Taiwan
- e. Several dairy farmers who are thinking of buying robots.
- f. Dietetics students as part of DairyWest's program to introduce these students to how milk and dairy products are manufactured (two tours).

I gave a presentation on how robotic dairies analyze for mastitis to a group of dairy producers

I was a committee member for a graduate student in the Ag Economics department looking at the economics of AMS installation.

The results from the facilities scenarios were published as an Extension factsheet plus this same data was used to co-author an invited article for Hoard's Dairyman (national and international magazine for dairy producers and allied industries).

Plan of Work:

None, this is the FINAL report.

The Role Of Soil Micronutrients In Mitigating The Effects Of Abiotic Stress On Wheat

Project Director

A Jacobson

Organization

Utah State University

Accession Number

1012939



The Role Of Soil Micronutrients In Mitigating The Effects Of Abiotic Stress On Wheat

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The overarching goal of this research is to investigate whether supplying plants with specific essential nutrients, such as Cu, Zn, Si, or P, can minimize or alleviate symptoms associated with abiotic stress in higher plants, and thus minimize losses, improve yields, and sustain food security. The specific objectives are to investigate:

- 1) The effects of micronutrients added in the form of metal-oxide nanoparticles on wheat seedlings under abiotic stress,
- 2) How the presence of a soil microbe affects the bioavailability of micronutrients added in the form of metal-oxide nanoparticles and their impact on wheat seedlings grown under abiotic stress, and
- 3) How the addition of compost to an organic, dry-land wheat system affects micronutrient bioavailability in wheat as determined by analysis of micronutrients in the leaves and grain and metal-fulvate complexes in the soil solution.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

Objective 1. The effects of micronutrients added in the form of metal-oxide nanoparticles on wheat seedlings under abiotic stress.

Early on, we investigated the role of CuO nanoparticles (NPs) on lignification of winter wheat (*Triticum aestivum* L. Deloris) seedlings by growing wheat in quartz sand amended with CuO NPs at 10 mg/kg and 300 mg/kg Cu for 7 days under fluorescent grow lights. This experiment demonstrated that the 300 mg/kg Cu dose was toxic to wheat causing shortening of roots and shoots. However, dying the tissue revealed that in the presence of 10 mg/kg Cu, increase lignification did occur in the wheat shoot tissue. Analysis of the tissue by FTIR suggested that lignin, cellulose, and hemicellulose were all enhanced in wheat shoot tissue of plants grown in the presence of 10 mg/kg Cu applied as CuO NPs, which could explain why wheat amended with CuO NPs remained erect when droughted relative to untreated controls. A key finding was that low doses of CuO NPs was necessary to realize their beneficial effects. Future studies were conducted and agronomic doses of the target nutrient in the NPs.

An initial study with winter wheat (L. Juniper) grown in sand amended with Hoagland solution and the beneficial microbe, *Pseudomonas chlororaphis* O6 in the presence CuO NPs, ZnO NPs, or SiO₂ NPs, under droughted and non-droughted conditions found no NP treatment effect of any of the three NPs at mitigating drought stress under the growing conditions. The growing conditions included a drought tolerant cultivar of wheat bred for the semi-arid west. These results together with a careful review of the literature led us to hypothesize that the mitigation of water stress in wheat amended with ZnO NPs was due to a correction of a Zn nutrient deficiency rather than a specific metal oxide NP effect. A study by Justin Deakin using two organically managed calcareous soils (1. Zn deficient Stingal Series, and 2. Zn sufficient Milville series) amended with ZnO NPs, bulk ZnSO₄ or an unamended control, found no significant difference Zn treatment effect with respect to drought mitigation in either soil. However, there was significantly more Zn uptake into the wheat tissue in the soils amended with ZnO NPs than with ZnSO₄. This is despite ZnSO₄ being more soluble at high pH than ZnO and there being no significant difference in plant available Zn extracted from the soils amended with ZnO NPs or bulk ZnSO₄. This is a significant finding about Zn uptake by wheat because wheat is deficient in Zn in many parts of the world affecting more than 2 billion people worldwide and resulting in the deaths of more than 0.5 million infants and children annually.

Finally, we are investigating meta-vivianite and chitosan-coated meta-vivianite nanoparticles for the ability to supply iron and phosphate to wheat growing on calcareous soil. Meta-vivianite is a partially oxidized ferrous phosphate mineral. Even though there is plenty of iron and phosphate in semi-arid, calcareous soil, due to the high pH of the soils, precipitation as iron oxides and hydroxides and calcium phosphate, and sorption to soil mineral and organic surfaces. We are investigating whether coating the meta-vivianite with chitosan will keep the vivianite mobile until it targets the rhizosphere where the more mobile ferrous iron can be taken up by the plant. Initial studies by Ph.D. student Li-Ting Yen and REU 2022 summer students suggest that the Fe uptake by wheat (monocot) and radish (dicot) is as high as uptake of Fe from iron-EDDHA chelate. If this result holds, it would offer a new type of Fe fertilizer – in particular, one that could be precipitated from wastewater with iron.

Objective 2. How the presence of a soil microbe affects the bioavailability of micronutrients added in the form of metal-oxide nanoparticles and their impact on wheat seedlings grown under abiotic stress.

Due to the complexity of working in a soil matrix, the initial nanoparticle studies were conducted in quartz sand amended with the nanoparticles (CuO, ZnO, SiO₂, and chitosan-coated meta-vivianite) and the beneficial bacterium, *Pseudomonas chlororaphis* O6 (*PcO6*) as a model microbiome. In our work with the microbe, we found that inoculating the wheat seeds resulted in a germination decrease of 13% in control plants, 34% for plants treated with 10 mg Cu as CuO NPs, and 24% for plants treated with 300 mg Cu and CuO NPs. Based on these results we changed our protocols to inoculate the soil with 10⁴ CFUs of *PcO6* rather than the seeds. We found that the wheat seeds (L. Juniper) contain endophytes that are generally outcompeted in the presence of *PcO6* but are not removed by surface sterilization with 30% H₂O₂ for 15 minutes. An unexpected result was that the presence of *PcO6* had a greater effect on the mitigation of water stress on the wheat seedlings than the NP treatments.

The summer REU students working with wheat and arugula planted in quartz sand amended with ZnO or CuO NPs found no treatment differences in control columns that were not inoculated with *PcO6*. However, the presence of *PcO6* enhanced Zn uptake by wheat, but not Cu.

Finally, an important observation in Justin Deakin's research working with an organic, dryland wheat soil (Zn deficient) and an

organic, compost amended soil (Zn sufficient) was that though wheat grown into the two soils in a growth chamber for 24 days demonstrated no Zn treatment effect and no response difference to drought stress, better plant vigor, higher shoot and root length, and greater biomass were observed in the organic, compost amended soil. We attribute the observation to a healthier, more resistant and robust microbiome that resulted in a more resistant and robust crop.

Objective 3. How the addition of compost to an organic, dry-land wheat system affects micronutrient bioavailability in wheat as determined by analysis of micronutrients in the leaves and grain and metal-fulvate complexes in the soil solution.

Due to external funding objectives and student interest, the focus of this objective turned to focus on understanding why the macronutrient P remained phytoavailable to dryland wheat growing on a calcareous soil up to 24 years after a single, large application of compost. As part of his PhD dissertation, Idowu Atoloye found that the high P phytoavailability resulted from the microbial cycling of organic P and the protection of that P within soil aggregates. The results of this work were published in January 2021. To better understand how the type of compost applied affects aggregation and aggregate stability, new plots were established in the fall of 2021. That research is ongoing.

Other Products

Data and Research Material - We have collected data regarding the effects of CuO, ZnO, vivianite, and chitosan coated vivianite nanoparticles on wheat uptake of Cu, Zn, Fe and P, respectively, in calcareous soils and in silica sand amended with dilute Hoagland solution and *Pseudomonas chlororaphis* O6. We developed a method for preparing nano-sized vivianite and coating it with chitosan while retaining its nano-size. We collected, homogenized and characterized over 200 kg of calcareous soils from northern UT that were used in completed experiments and are continuing to be used in new research. We established test plots treated with four types of compost (hardwood rich, softwood rich, slaughterhouse sources, and straw) at rates of 50 Mg/ha each. In addition, the plots were split with 1/2 receiving feather meal as a nitrogen source. Now that they are established, the compost plots will be planted, harvested, and monitored regularly for soil health and grain properties.

Briefly describe how your target audience benefited from your project's activities.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Due to student interest and sources of additional external funding, the focus of objective three shifted to investigate P cycling in organic dryland soils amended with compost and effects on soil health particularly aggregation, water infiltration and soil penetration. New plots were established with different types of compost. Two papers were published on this work regarding P cycling and the long term phytoavailability of organic P, and effect of compost on C-dynamics in the soil. This work is ongoing.

Training and Professional Development:

This project has contributed to a Ph.D. earned by Idowu Atoloye in Dec. 2020 for his work on P uptake and cycling in dryland wheat amended with compost. It has also contributed toward an MS for Justin Deakin (expected Dec. 2022) working on the mitigation of drought stress in wheat through the application of ZnO nanoparticles; and MS for Preston Christensen (expected Dec. 2022) working on how the application of compost on dryland wheat affects soil health and grain quality; and a PhD for Li-Ting Yen (expected August 2023) who is studying the mitigation of salinity stress on wheat through the application of vivianite (ferrous phosphate) and chitosan coated vivianite nanoparticles. During their research, Idowu was trained to use NMR. Li-Ting Yen and Justin Deakin were trained to use SEM-EDS. All the students became proficient in instrumental analysis, common soil health analyses and assays. They each became proficient in preparing posters and talks on their research that they presented at regional and national/international meetings. They each also mentored undergraduate students in the lab. Each graduate student met regularly with me as their major advisor for discussion in my office, but also in the lab when they were learning new techniques.

Dissemination:

The results of this research have been disseminated through five peer reviewed publications, and four publications in preparation for submission within the year. In addition, oral and poster presentations of the research have been presented every year at the Soil Science Society of America Annual Meetings, as well as several presentations at the Western Nutrient Management Meetings. We have welcomed two Native American students into our lab for ten weeks through the NSF: Research Experience for Undergraduates (REU) Plant STEM program at USU in 2021. The students were from the Blanding Campus, a two-year institution, and gave a presentation at the college regarding their experiences. One of the students returned to USU this summer to continue her education toward a B.S. at USU. In 2022, we had two new REU students in our lab. One will present their research at the SACNAS meetings in Puerto Rico in October. Both went back to their universities with copies of their research poster to advertise undergraduate research opportunities to their classmates. Finally, the first undergraduate student in the program, completed a undergraduate research program in biology and presented her research completed in the College of Agriculture and Applied Sciences to students and faculty in the College of Science. Later that year I presented her research at the Soil Science of America meetings.

Products/Presentations:

Britt, D. W., Jacobson, A. (Presenter & Author), Hortin, J. (Author Only), McLean, J. E., Anderson, A. J., Soil Science Society of America International Soils Meetings, "From Implications to Applications: Engineered Nanoparticles in the Rhizosphere," Soil Science Society of America, Salt Lake City, UT. (November 7, 2021 - November 11, 2021)

Deakin, J. (Presenter & Author), Cartwright, A. (Author Only), Potter, M. (Author Only), Sparks, D. (Author Only), Hortin, J. (Author Only), Anderson, A. J. (Author Only), Britt, D. W. (Author Only), McLean, J. E. (Author Only), Jacobson, A. R. (Author Only), Student Research Symposium (SRS), "Is Mitigation of Drought Stress By Zinc Oxide Nanoparticles Driven By a Nano-Specific Mechanism or Mitigation of Micronutrient Deficiency?," Utah State University, Virtual. (April 14, 2021)

Deakin, J. (Presenter & Author), Cartwright, A. (Author Only), Potter, M. (Author Only), Sparks, D. (Author Only), Hortin, J. (Author Only), Anderson, A. J. (Author Only), Britt, D. W. (Author Only), McLean, J. E. (Author Only), Jacobson, A. R. (Author Only), Western Nutrient Management Conference, "Is mitigation of drought stress by zinc oxide nanoparticles driven by a nano-specific mechanism or alleviation of micronutrient deficiency?," Virtual. (March 2, 2021 - March 4, 2021)

Jacobson, A. (Presenter & Author), Cartwright, A. (Author Only), Deakin, J. W. (Author Only), Hortin, J. (Author Only), Jackson, K. (Author Only), Potter, M. (Author Only), Sparks, D. (Author Only), Anderson, A. J. (Author Only), McLean, J. E. (Author Only), Britt, D. W. (Author Only), Soil Science Society of America Annual Meeting, "Do Metal Oxide Nanoparticles Prime Crop Defenses Against Water Stress," ASA, CSSA, SSSA, San Antonio, TX, USA. (November 10, 2019 - November 13, 2019)

Deakin, J. W. (Presenter & Author), Potter, M. (Author Only), Cartwright, A. (Author Only), Jackson, K. (Author Only), Hortin, J. (Author Only), Sparks, D. (Author Only), McLean, J. E. (Author Only), Britt, D. W. (Author Only), Anderson, A. J. (Author Only), Jacobson, A. R. (Author Only), Soil Science Society of America Annual Meeting, "Effects of Zinc Oxide Nanoparticles on Drought Stress in Winter Wheat," ASA, CSSA, SSSA, San Antonio, TX, USA. (November 10, 2019 - November 13, 2019)

Deakin, J. W. (Presenter & Author), Potter, M. (Author Only), Hortin, J. (Author Only), Cooper, J. (Author Only), McLean, J. E. (Author Only), Britt, D. W. (Author Only), Anderson, A. J. (Author Only), Jacobson, A. (Author Only), PSC Graduate Student Seminar, "Effects of Zinc oxide nanoparticles on drought tolerance in winter wheat," Plants, Soils and Climate Department, USU, Logan, UT. (April 1, 2019)

Deakin, J. W. (Presenter & Author), Matthew, M. (Author Only), Hortin, J. (Author Only), Cooper, J. E. (Author Only), McLean, J. E., Britt, D. W., Anderson, A. J., Jacobson, A., PSC Student Showcase, "Effects of ZnO nanoparticles on drought tolerance in winter wheat," Plants, Soils and Climate Department, USU, Logan, UT. (March 25, 2019)

Jacobson, A. (Presenter & Author), Deakin, J. (Author Only), Hortin, J. (Author Only), Powelson, D. (Author Only), McLean, J. E., Britt, D. W., Anderson, A. J., Soil Science Society of America International Soils Meetings, "Mitigation of water stress in wheat grown in sand amended with ZnO nanoparticles," Soil Science Society of America, San Diego, CA. (January 6, 2019 - January 9, 2019)

Other Products

Data and Research Material - We have a completed data on the effect of CuO, ZnO, and SiO₂ nanoparticles at doses ranging from 0-30 mg/kg Cu, 0-20 mg/kg Zn and 0-200 mg/kg Si on the photosynthetic output, chlorophyll fluorescence, dry tissue mass, and leaf water contents, Zn and Cu concentrations in the shoots, for winter wheat (juniper) grown in quartz sand (Unimin 4060) inoculated with *Pseudomonas chlororaphis* O6.

We have approximately 200 kg each of three well-characterized soils (particle size distribution, pH, ECe, CEC, plant available

metals, total organic carbon, total inorganic carbon) of three different soils to use in the experiments for the duration of the project, and approximately 300 kg each of two other well characterized soils: one that is highly deficient in zinc and another that is borderline Zn deficient.

Data and Research Material - We have data on the effect of CuO, ZnO, and SiO₂ nanoparticles at doses ranging from 0-30 mg/kg Cu, 0-20 mg/kg Zn and 0-200 mg/kg Si on the photosynthetic output, chlorophyll fluorescence, dry tissue mass, and leaf water contents, Zn and Cu concentrations in the shoots, and preliminary values for root metabolites in the rhizosphere for winter wheat (juniper) grown in quartz sand (Unimin 4060) inoculated with *Pseudomonas chlororaphis* O6.

We have approximately 200 kg each of three well-characterized soils (particle size distribution, pH, ECe, CEC, plant available metals, total organic carbon, total inorganic carbon) of three different soils to use in the experiments for the duration of the project.

Data and Research Material - We have preliminary data on the effect of CuO and ZnO nanoparticles at doses ranging from 0-300 mg/kg Cu and 0-300 mg/kg Zn on the photosynthetic output and chlorophyll fluorescence of winter wheat (juniper) grown in quartz sand (Unimin 4060) inoculated with *Pseudomonas chlororaphis* O6.

We collected, dried, sieved to < 2-mm, and thoroughly homogenized approximately 200 kg each, of three different soils to use in the experiments for the duration of the project. We are in the process of characterizing the soils (particle size distribution, pH, ECe, CEC, plant available metals, total organic carbon, total inorganic carbon).

Agriculture and Natural Resources: Agricultural Productivity

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7001690



Agricultural Extension Education in Sevier County

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In 2022, agriculture continues to be an important part of Sevier County Utah. USDA NASS reported that Sevier County farmers and producers received \$108,133,000 in cash receipts, of which 20% was from agronomic crops and 80% from Livestock. Alfalfa hay continues to be the most important agronomic crop in Sevier County with 105,000 tons produced. In Sevier County, there were 691 farms, and 1,243 farmers. Crop producers and stakeholders depend on research-based information and technical assistance as they make critical decisions regarding crop management policies, soil fertility, irrigation optimization during prolonged drought, and weed and insect management. They turn to USU Extension for unbiased, researched-based educational information and technical assistance to help them diagnose agronomic crop problems, find solutions, and profitably and sustainably grow agronomic crops.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In 2022, USU Extension assisted producers by providing unbiased, research-based information and recommendations via farm visits, field scouting, in-person and virtual workshops, publications, text messages, phone calls, and remote live radio programs.

Briefly describe how your target audience benefited from your project's activities.

J. Gale reported the program focused on increasing crop quality, food supply, and food safety. The program included technical assistance to help producers increase profitability from higher crop yields with lowered input costs. Another component was integrated pest management which dealt with environmental sustainability and good land stewardship. This component included teaching growers how to identify and better manage pests and weeds, understand economic threshold levels, and pesticide recommendations.

Briefly describe how the broader public benefited from your project's activities.

J. Gale reported the Agricultural Extension Education program in Sevier County positively affected sustainable crop production on 108,992 acres of farmland, 40,129 acres of harvested cropland, and 49,440 irrigated acres. Extension education programs are critical to providing producers with the information they need to improve their productivity.



Beginning Beekeeping Extension Education

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In recent years, beekeepers have experienced a 20-30% increase in hive losses statewide according to the Utah Department of Agriculture and Food Apiary program. New beekeepers often face challenges in keeping their hives healthy and keeping them alive overwinter. According to the Utah Department of Agriculture and Food Apiary program website (UDAF, 2022), “Varroa mites and the diseases they carry represent the single biggest challenge facing honey bees in most areas of the world.” In Utah, the majority of hive deaths are due to Varroa mite infestations caused by poor hive management. Therefore, proper Varroa mite management should be the top priority for beekeepers. Beekeepers must regularly monitor their hives for this parasite and treat their colonies with an effective Varroacide when mite levels are too high. While there are many educational resources available on Varroa mites, the amount of information can easily be overwhelming for new beekeepers.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

A. Walker Bravo developed the USU Extension Thriving Hives program in 2016 to provide educational hands-on experiences to novice and advanced beekeepers. The program initially focused on advanced beekeeping workshops. However, due to the increased demand by new beekeepers for educational opportunities, the program transitioned to facilitate beginning beekeeper classes. In Salt Lake County, the Thriving Hive Beginning Beekeeping program is a season-long (February through October) workshop series offered to individuals who are interested in beekeeping but do not have bees or are very new to apiculture. The Thriving Hive series includes lecture and hands-on learning components and is taught by both USU faculty and guest speakers. The hands-on portion of the Thriving Hive program is facilitated at Wheeler Historic Farm in Murray where USU Extension maintains a 10-15 hive apiary. In small groups, participants are assigned a hive that they maintain throughout the season, and they are responsible for the management and decision-making of the hives with assistance from the facilitators.

Briefly describe how your target audience benefited from your project's activities.

A total of 28 individuals participated in the 2022 series, and attendance varied throughout the season. Attrition throughout the year was expected since the course is long and requires commitment from participants. Based on retrospective evaluation results ($n=13$), no participants entered the series with above average or excellent knowledge on the topics. However, results showed a major improvement in participants' knowledge of all topics, specifically Varroa mites, and the services performed by the county bee inspector after the series. Evaluation results also indicated 100% of respondents strongly agreed that the series “increased my comfort level in working with bees”, “increased my confidence in being a beekeeper”, “help me be a more successful beekeeper”, and “gave me the confidence to start keeping bees. While participants rarely monitored and treated for Varroa mites before the series, After the series, participants indicated strong intentions to implement Varroa mite management practices.

The evaluation also gathered open-ended data from participants. Most participants (92%) indicated that they would implement skills learned in these classes. One participant said they would monitor colonies for pests and disease, utilize hive inspection services, and prepare for successful overwintering. They also said, “seeing the insect specimens and photos were very helpful”. Another said, “when I get a hive I plan to do routine checks. Especially in the spring to check that the queen bee is laying eggs, any signs of disease like American/European Foulbrood and will continue to follow the handouts to monitor the lifecycle of the bees. I also plan on checking for mites using either the powder or alcohol method as well as using the resources provided to treat for mites properly.”

When asked about the value of the Thriving Hive Beginning Beekeeping program, one participant said, “This class is instrumental in helping educate novice beekeepers as well as those interested in learning more about helping to support honey bees. The wealth of resources provided help educate and prevent disease spread and ensures proper bee-keeping techniques are used.” Another said, “The class emphasized how to be better stewards of bees, and the responsibilities to our neighborhood and community, especially when it came to the varroa population. I am amazed each time I learn more about

bees, bee behavior, and bee biology. The class also highlighted the partnership that should exist between the local beekeeper and the bee inspector. Because of the class, we called out our local inspector to ensure that we were on the right path as new beekeepers. I wish that they offered a follow-up class in between "newbees" and the master class!"

Briefly describe how the broader public benefited from your project's activities.

Evaluation results of the Thriving Hive Beginning Beekeeping program in Salt Lake County indicated participants experienced an increase in their knowledge of beekeeping and intended to properly monitor for and treat Varroa mites. With close collaboration with the Utah Department of Agriculture and Foods Apiary program, the Thriving Hive program effectively responded to the apiculture needs in Utah. Moving forward, the Thriving Hive Beginning Beekeeping program will continue to deliver hands-on experiential education to novice beekeepers in Utah. With positive evaluation results and increased demand for hands-on programming, a coordinator will be hired for the 2023 series to increase the program's capacity to provide individualized learning opportunities for participants.



IPM Demonstration Farms

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Pesticides, both organic and conventional, are often necessary for the production of healthy crops and landscapes. However, Integrated Pest Management (IPM) practices promote the use of non-chemical options first and pesticides as the last resort. A high level of IPM implementation uses a mix of these practices to prevent crop and ornamental plant losses, improve profits, and protect human health and the environment (USDA, 2018). Led by M. Murray, the IPM program identified an ongoing need for IPM education by reviewing comments and experiences of clientele in the 'Utah's Gardening Experts' Facebook group. This group was created in 2019 by USU Extension faculty and staff to provide research-based information direct to clientele on social media. The IPM team saw a need for a practical demonstration site due to the recurring questions and comments from clientele relating to non-chemical options to manage arthropod pests and plant diseases. Pests cause economic loss and aesthetic damage which can often be prevented or maintained at low levels by using proper IPM practices.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In the spring of 2022, the IPM program established a vegetable IPM farm to test and demonstrate various IPM techniques for vegetable production. This one-acre farm is located at the Utah Agricultural Experiment Station Greenville Farm, adjacent to USU main campus in Logan, UT. The main goal of this farm was to provide a "real-life classroom" to demonstrate to clientele the cultural, mechanical, and biological control methods used to manage pests. To showcase farm activities to clientele, the USU Extension IPM team hosted a tour in July of 2022. Topics included mulch use in dahlia production (Dr. Claudia Nischwitz), row covers, trap cropping (Nick Volesky), beneficial insect identification (Zachary Schumm), and weed management techniques (Bridger Carey). To complement the tour, we created videos (*Tomato Spotted Wilt Virus Overview* and *How to Manage Cabbage Aphids*) and used our existing social media platforms to reach a wide audience. We posted 11 updates of the work on the farm throughout the season to followers of "USU Extension – Utah Pests" Facebook (1,737 followers) and "USU Extension – Utah Pests" Instagram (1,174 followers). At the end of the tour, we asked participants to complete a retrospective evaluation to assess their knowledge of IPM topics and intentions to adopt best IPM practices at their own site.

Briefly describe how your target audience benefited from your project's activities.

The non-chemical pest control methods used on the farm were successful. The IPM weed management program used minimal labor and resulted in a weed-free area around the crops, and approximately 75% coverage of weeds elsewhere. Insect exclusion via covering crops with mesh netting or spun fiber is not commonly used by Utah farmers, but we found it to be 100% successful in the demonstration farm. The sunflower/sorghum trap crops harbored true bugs and other pests 50% more than what was found on the vegetable crops. The mulching trial for tomatoes and dahlias showed significantly less incidence of disease and pest presence.

A total of 48 individuals participated in the on-farm workshop, and a total of five (5) CEU credits were awarded to attendees with a pesticide applicator's license. Based on the retrospective evaluation results ($n = 28$), there was an improvement in participants' knowledge of all IPM topics covered in the workshops. Results indicated there was a 73% increase in participants' knowledge of general IPM tactics, a 78% increase in row cover use to control pests, a 100% increase in trap crop/companion planting, a 32% increase in weed control methods, and 65% increase in pest identification.

The evaluation also assessed participants' intentions to implement IPM methods demonstrated at their own sites. Participants were likely to use row covers, trap cropping, and plastic mulch. The online videos and social media interactions led to follow-up questions regarding IPM. The *Tomato Spotted Wilt Virus Overview* video reached over 1,500 individuals and had 644 views on Facebook and 269 views on Instagram. The *How to Manage Cabbage Aphids* video has reached over 1,100 individuals and has 593 views on Facebook.

Briefly describe how the broader public benefited from your project's activities.

Evaluation results from the IPM demonstration farm indicated participants increased their knowledge of vegetable IPM practices and intended to apply what they learned in the workshop. The demonstration farm effectively responded to the needs and interests of stakeholders by providing outreach education on using IPM to manage insect and disease pests on Utah farms and home landscapes. Our outreach activity provided participants with the skills to identify, monitor, and manage pest problems, which can ultimately reduce pesticide use. The potential long-term outcomes of IPM adoption include reduced human and environmental exposure to pesticides and reduced yield losses for producers. Moving forward, the USU Extension IPM Program team will continue to use the demonstration farm and deliver research-based education and outreach opportunities to more Utah stakeholders. In the future, we hope to routinely use the farm for tours, videos, and experiential learning opportunities for Utahns.



Inclusive Farmers Markets

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Farmers markets play a vital role in supporting communities by providing gathering spaces and fostering local agriculture and economic development (Alonzo, 2017). However, market demographics are predominantly white across staff, vendor, and customer populations, posing high barriers to entry for people of color (Alkon & McCullen 2010). Diversity within the state of Utah is steadily increasing. It is projected that one in three Utahns will identify as nonwhite by 2060 (Kem C. Gardner Policy Institute, 2021). Unfortunately, minorities in Utah have unfavorable health and wealth disparities compared to their white counterparts (Kem C. Gardner Policy Institute, 2021). The Utah Governor's Office posits, "women, people of color, and LGBTQIA+ communities in Utah have unique historical, socio, cultural, and economic barriers preventing them from participating fully in our state" (One Utah, 2021, p. 2). As a result, the Utah Farmers Market Network (UFMN) prioritized exploring how farmers markets could be more welcoming and inclusive to all individuals regardless of racial background. The UFMN also sought to generate a greater level of interest and concern among managers of farmers market on equity and inclusion.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The UFMN used USDA funding to convene a virtual Diversity, Equity, and Inclusion (DEI) Community of Practice (CoP). The goal was to explore how markets could be more welcoming and inclusive to historically excluded populations. The CoP was co-facilitated by the UFMN coordinator and the network's Diversity Assistant, and supported by Utah State University (USU) faculty and researchers throughout the planning and implementation stages. Members of seven (7) Utah farmers markets convened at least twice monthly to explore basic DEI concepts and create personalized DEI Strategic Plans for their markets. The CoP participants collected baseline data using tools created by the co-facilitators for the purposes of measuring inclusivity. This data was then compared to data collected by co-facilitators and USDA Census data. Each market established at least three personal, market, and/or organizational goals that were strategic, measurable, ambitious, realistic, time-bound, inclusive, and equitable.

The CoP's target audience were low-income and SNAP recipients from historically excluded and oppressed groups such as Black and Indigenous People of Color (BIPOC), women, religious minorities, and LGBTQ+ individuals. The actual participants of the CoP were eight farmers market managers ($N = 8$), representing seven (7) Utah markets. Each manager applied and were selected on the basis of their current understanding of DEI, learning readiness, and ability to commit to the CoP. Markets were compensated \$1000 to participate in six (6) out of eight (8) 90-minute sessions, which included three (3) to five (5) hours of preparatory work by each participant. Eighty-seven percent (87%) of participants received the full stipend.

Briefly describe how your target audience benefited from your project's activities.

As reported by R. Brain McCann and team, evaluation results indicated 100% of the eight (8) participants who completed the CoP had an increased understanding of the demographic makeup and lived experience of the target audience. Many participants reported a more developed frame of reference concerning issues of DEI, which permeated their personal and professional lives. For example, one participant stated, “I feel like I have a whole new lens - I now see things in a different light and am aware of injustice happening around me.” Another reported, “I did not realize how many barriers there are, and have been, for those who are marginalized and how it affects every interaction they have throughout their days and lives.”

Participants have committed to implementing interventions within their farmers markets and organizations in an effort to be more welcoming and inclusive. Some examples of the goals set by farmers market managers include rewriting mission statements to include DEI principles, recruiting more diverse job candidates, updating social media to reflect the current diversity of their community, and improving wheelchair accessibility at their market.

Participants also commented on the sense of community the CoP fostered and reported an appreciation for the accountability around continuing equity work in their field. Another participant shared, “This is one of the most beneficial things I have signed up for in my four-year career as a market manager. Not only has it helped me in my current role, but it will help me in years to come as DEI is at the forefront of many initiatives.”

During UFMN’s annual Market Manager Forum in early 2022, three (3) members of the CoP presented on a panel to share their experiences. There was an active discussion between panelists and audience members during the presentation, after which 100% of the managers ($n = 8$) who attended this session reported that they found the DEI panel beneficial.

Briefly describe how the broader public benefited from your project's activities.

The markets that participated in the CoP now have a variety of tools they can use to deepen their personal understanding of DEI and implement changes within their market organizations and their physical markets. Current and future vendors, customers, and staff will benefit from the DEI interventions by these farmers markets. The UFMN team is currently designing inclusive welcome signage that will be available to farmers markets managers who participated in the CoP. A DEI best practices document is also being created, along with a number of reports. The network plans to seek more funding to support another CoP, collect data on long-term impacts to the participating markets, and conduct a longitudinal study of changes in diversity (vendors and patrons) across Utah’s farmers markets. All seven markets that participated in the DEI CoP have committed to centering DEI in their policies and procedures and have chosen to lead the CoP during network transitions. One participant noted, “I think a group like this can be started anywhere it just needs some brave leadership and guidance. I’m grateful for this opportunity and to have deepened my understanding of DEI in the farmers market context.”



Preventing Injury Among Master Gardeners

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Gardening is shown to have many health benefits, especially in older adults (Kaplan, 1973; Wang & MacMillan, 2013), but injuries are common (Hall, 2018; Powell et al., 1998). While gardening positions have been studied, there is insufficient evidence of best practices for gardening posture and technique to minimize or prevent pain and injury (Nicklett et al., 2014; Park & Shoemaker, 2009). Non-fatal injury data on personal home gardening is limited, but data for professional landscaping and groundskeeping can help shed light on the nature and source of injuries experienced by gardeners. That is, repetitive strain injuries that affect hands, back, knees, and ankles are caused in part by unsuitable movements, positions, and tool use (US Bureau of Labor Statistics, 2021). Although the prevalence of injury is small compared to other leisure activities, recovery takes time away from this beneficial activity and can involve various types of treatment (Hall, 2018; Park & Shoemaker, 2009; Powell et al., 1998). Educating gardeners on proper posture and tool use can help prevent or minimize injury.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

G. Murza developed the *Adaptive Gardening and Minimizing Injury with Tools, Techniques, and Stretches* workshop that combines classroom instruction and hands-on practice to teach participants best practices, proper postures, and correct tool use to help prevent and minimize pain and injury while engaging in common gardening activities. To date, four workshops were presented in three urban counties (i.e., Utah, Salt Lake, and Weber) to 53 Master Gardener Volunteers (MGVs) and horticulture staff. Three workshops were taught in person and one was taught as an online class with a similar interactive format. Program Coordinators supplied classroom space for the in-person presentation, gardening tools for participants to

practice with, and outdoor garden space. After completing the classroom portion, participants practiced proper techniques and postures while using tools and doing common gardening activities under the guidance and instruction of USU Extension faculty. Participants first practiced indoors without tools, then with tools, and then moved outdoors to “put it all together” in the garden space. Alternative movements addressed mobility challenges that some volunteers experienced, such as limited shoulder movement and knee surgery.

Briefly describe how your target audience benefited from your project's activities.

A retrospective pre-post survey was developed to assess short-and-medium-term outcomes. The survey was administered to participants two to four weeks after the workshops to assess knowledge gain and early behavior adoption. To assess medium-to-long-term outcomes, a six-month follow-up survey was administered to assess continued behavior utilization and perceived change in pain level while gardening. Thirty-eight participants ($n = 38$) responded to the first short-to-medium-term survey, yielding a 72% response rate. Knowledge was assessed for four injury prevention concepts: (a) best practices, (b) safe movements, (c) stretches and exercises, and (d) common challenges.

Based on the short-term evaluation results, participants improved their knowledge on all three major concepts; best practices for gardening, safe movement in gardening, and stretches and exercises to ease pain and discomfort. In addition, early behavior adoption was assessed 1 month after the workshops, and results showed most participants adopted recommended practices for gardening behaviors related to using proper stances, and stretching. In the six-month follow-up survey, 25 participants ($n = 25$) reported their continued behavior engagement in best practices. The average perceived pain level of participants decreased from 4.65 to 3.00 (on a 10-point scale).

Briefly describe how the broader public benefited from your project's activities.

Gardening injuries occur mainly due to improper posture and tool use. Workshop participants shared their experiences of similar pain and injury when gardening. When discussing treatment strategies, they also shared their use of various pain management treatments, including taking pain medication as needed. While pain medication can be an appropriate treatment option for chronic pain, certain medications, like opioids, have the potential for addiction and should not be taken if not needed (CDC, 2019). Even if participants do not use medication to relieve pain, the fact that they experience pain due to poor gardening techniques suggests the need for this workshop and its potential value for MGVs.

Survey results suggest that after the workshop, the majority of participants adopted best practices relating to gardening behaviors of proper posture and stretches for garden safely. While MGVs were the primary audience, the content and format of the workshops may also benefit anyone active in gardening. Therefore, we plan to incorporate demonstration videos to reach a wider audience and improve accessibility to the content. While some participants may not be able to practice with real tools or receive real-time feedback, it allows them to practice on their own and view the movements in action.



Responsive Programming on Drought Management

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

R. Briggs conducted a needs assessment in late 2021 to understand issues affecting farmers and ranchers in Rich County Utah. As a rural agricultural area, Rich county depends on agricultural production for employment and income.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Briggs conducted several educational activities in 2022 for agricultural stakeholders. Activities included drought workshops and a complementary producers' newsletter. Briggs noted participants gained new knowledge to help them make informed decisions about their individual operations in light of prolonged drought.

Briefly describe how your target audience benefited from your project's activities.

With respect to livestock producers, higher quality bulls are now being selected based on information from the workshops and newsletters, which, in turn, influenced approximately \$61,200,200 in livestock production. Briggs's agricultural education program made a positive impact on Rich County by supporting and informing ranchers and farmers. The short-term outcomes related to increased knowledge and greater levels of interest by participants.

Briefly describe how the broader public benefited from your project's activities.

Producers have already used the information and resources to increase the quality of their livestock, crops, and income. This responsive drought program is important to sustaining the economic productivity of Rich county.



Utah Agriculture in the Classroom Preservice Teacher Seminar

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Agriculture in the Classroom organizations implement programming to increase agricultural literacy among pre-kindergarten, 12th-grade teachers, and students (NAITCO, 2020). Led by D. Stewardson, the *Utah Agriculture in the Classroom* (AITC) program seeks to increase pre-service teachers' agricultural literacy, provide lesson plans for future use, and increase teachers' self-efficacy in using agriculture as a context for addressing content standards. The AITC evaluated their program in 2022 with the following goals; (a) to evaluate the short-term preservice teacher seminar outcomes, including teacher perceptions of agriculture, use of agriculture as a context to teach curriculum standards, and intended use of seminar resources, and (b) to evaluate the mid-term preservice teacher seminar outcomes including actual use of seminar resources, self-efficacy to use agriculture as a context for addressing curriculum standards, and student perceptions of agriculture after the use of these lessons.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The target audience for AITC is pre-service agricultural teachers in Utah. An approach that AITC uses to increase agricultural literacy is partnering with universities across the state of Utah including Weber State University, Utah Valley University, University of Utah, Brigham Young University, and Utah State University to host preservice teacher seminars reaching nearly 600 elementary education teachers annually. These one- to three-hour seminars occur during the fall and spring semesters at the respective institutions and are typically held face-to-face, except for Zoom presentations necessitated by the COVID pandemic. A retrospective evaluation framework was used to assess the usefulness of resources to educators and determine if program outcomes regarding agricultural literacy were met.

Briefly describe how your target audience benefited from your project's activities.

The evaluation results pertain to AITC participants since 2017; 584 preservice teachers responded to the short-term survey. When asked about their growth as a result of the seminar, 70% of the participants indicated they agreed or strongly agreed their agricultural knowledge increased after the seminar. Most participants (98%) stated it was likely or very likely they would use the resources provided in the seminar and explore the Utah AITC website for further resources. Eight (8) questions addressed the delivery of the seminar; all responses were positive. Of the 584 responses, more than 85% rated the pace, organization, and relevance of the presentation as very good.

For the medium-term survey, twenty-three participants ($n = 23$, response rate = 10%) completed the survey, with a high number of participants being unreachable. Of the 23 respondents, one graduated from their undergraduate teaching program in 2018 (4%), five in 2019 (22%), 12 in 2020 (52%), four in 2021 (18%), and one had not yet graduated from college (4%). Upon graduation, 21 respondents taught for some duration; 18 (86%) are currently teaching, and 2 (9%) entered the teaching profession, but at the time of the survey were no longer teaching. One participant was not currently teaching but was working with elementary students and teachers in some capacity.

A desired outcome of the seminar was to increase the teachers' self-efficacy in using agriculture as a context to meet curriculum standards. Mid-term respondents felt somewhat comfortable using agriculture as a context to teach lessons in their classes ($n = 22$, $M = 2.67$, $SD = 0.8$). While teachers indicated comfort using agricultural themes within their lessons, several ($n = 6$) stated they had not used lessons from the Utah AITC website in their classrooms. More respondents ($n = 11$) indicated they had not yet used these lessons but planned to in the future.

Of the lessons teachers did use in the classroom, most lessons (50%, $n = 4$) were tied to science educational standards, while others were connected to nutrition/health (25%, $n = 1$) or reading (25%, $n = 1$). Participants were asked to comment as to why they had not used lessons from the Utah AITC website following participation in the webinar. The word "forgot" was used

three times, one person stated they were unsure how to incorporate the lessons, and one person stated they have a long list of requirements to accomplish within their class; therefore, these lessons did not fit ($n = 20$). One respondent indicated they would not use the lessons because their values did not align with the material.

Briefly describe how the broader public benefited from your project's activities.

The results have provided insights for Utah AITC program planners to improve the curricula and program implementation model. The short-term results indicate preservice teachers found the seminar informative and they planned to use these in the future. However, mid-term results indicate participants did not follow through in their own classrooms. To encourage graduates to use the agricultural literacy materials, Utah AITC will seek new ways to follow up or engage with teachers in professional learning communities during their first few years of teaching to remind the new educators about the resources and how to use them to address curricular standards. Utah AITC staff will also consider the timing of the seminar within the undergraduates' course sequence to ensure the most effective placement for more immediate implementation of the resources. These improvements may lead to an effective program that can empower teachers to conduct classroom lessons aimed at improving the agricultural literacy of students.

Critical Issue

Healthy, Financially Secure Families

NC1030: Sustainable and Resilient Systems: Transformative Response

Project Director

Yoon Lee

Organization

Utah State University

Accession Number

7001178



NC1030: Sustainable and Resilient Systems: Transformative Response to Disruptions by Families, Businesses, and Communities.

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The NC 1030 research team has conducted, and published research focused on family firms and policy for more than twenty years. In this new project, the team aims to continue and extend the previous NC 1030 research project objectives. In this new project, the team not only explores the patterns of success and responses to disruptions, but also focus on transformative and adaptive change necessary to increase resilience and sustainability practices.

The main objectives of this new NC 1030 project include: To identify and measure the sources of major change and disruption and the structural barriers that impact the family/household, the business or the community (Objective 1); to identify and measure transformative responses to the positive and negative impacts of change and disruption on the family/household, the business, or the community (Objective 2); and to determine and inform policy or practice related to the wellbeing of the family, the business, or the community (Objective 3).

The project will have multiple outreach outlets that reflect the diversity of the NC 1030 membership. Research findings will be shared through scholarly publications in research journals that span multiple disciplines, and will be presented at national and international conferences.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

- I worked on a manuscript with my graduate student, Heather Kelley. The manuscript is titled, “Work-Family Balance and Perceived Business Outcomes Among Copreneurial and Noncopreneurial Small Business Owners.” This study looked at the differences between copreneurial and noncopreneurial small business owners. We submitted this article to *Journal of Family and Economic Issues*; it is currently under review.

- I worked on a manuscript titled, “Love of Work or Love and Work: Does Business Owner Compulsion to Work Pay Off?” This research investigated factors associated with small business owners behaving as compulsive workers. We submitted our completed manuscript to the *Journal of Small Business Management* in July 2022; however, this manuscript was rejected for a possible consideration of publication in this journal. Since we received important and valuable comments from the reviewers, we are currently working on revising this manuscript and planning to submit to the *Entrepreneurial Research Journal* in Spring 2023.

- With other NC1030 group members, I worked on a manuscript titled, “Give, Sell, or Liquidate: The Effect of Socioemotional Wealth on Small Business Owner Exit Intentions.” This manuscript used data from the 2019 Small Business Values Survey (SBVS). We presented a paper presentation at the 2022 US Association of Small Business and Entrepreneurship (USASBE) Conference. This study focused on exploring the impact of socioemotional wealth on the intention to use four different exit strategies by small business owners.

- Working with my graduate student, Heather Kelley, I published a brief report in the PIFB Quarterly Newsletter Summer 2022. The article is titled, “Succession Planning Expectations Among Women-Owned Small Businesses.” This study examined the succession planning expectations among women-owned small businesses, while focusing on how succession planning expectations differed by gender.

- I published a brief report in the PIFB Quarterly Newsletter Summer 2022. The study is titled, “Social Media Use and Business Profitability Among Small Businesses”. The purpose of this study was to understand the role that social media and internet use play in the perceived business success among small business owners. Additionally, the effects of social media and internet use were also investigated. I worked on this manuscript with my graduate student, Heather Kelley.

- Additionally, working with NC1030 group members, I published a brief report in the PIFB Quarterly Newsletter Fall 2022. The article is titled, “Pros and Cons of Being a Workaholic.” This study examined who is more likely to be a workaholic. The data analysis showed that workaholic owners were more likely to be male, have more children at home, have lower levels of family/business functioning (FB-BRAG scores), be younger, be a minority, work more hours per week, and be in the service industry.

- In collaboration with NC1030 members, I contributed to a manuscript titled, “In the Depths of Despair: Lost Income and Recovery for Small Businesses During COVID-19.” This manuscript uses data from the 2020 Small Business Disaster Survey. This study focused on small business owners’ experiences during the COVID-19 pandemic and looked at a variety of factors that were associated with the likelihood of experiencing income loss during this time.

- I contributed to a paper presentation accepted by the 2023 USASBE Conference titled, “Use of Family Business Adjustment Strategies During COVID: A Comparison Between Homebased and Non-Homebased Businesses.” This study uses data from the 2021 Small Business Adaptive Responses to Disaster Events Survey. This study examines the impact of COVID-19 on small business owners’ adjustment strategies and their associated outcomes. I contributed to the conceptual framework section of this study.

Outcomes and Impacts

Findings from the studies completed this year could help small business owners prepare for continuity and success, and keep sustainability from disruptions such as economic downturn and the COVID-19 pandemic. Specific contributions from each of these studies are outlined below.

- The findings from “Work-Family Balance and Perceived Business Outcomes Among Copreneurial and Noncopreneurial Small Business Owners” suggested that copreneurs were significantly more likely than noncopreneurs to report conflicts about decisions related to their work and family lives, and were also more likely to report negative work-to-family spillover and negative family-to-work spillover. These findings also suggested that while copreneurs might perceive their business has being more profitable and more successful than noncopreneurs, they might benefit from more support in learning how to integrate their family/personal and professional responsibilities.

- The findings from “Love of Work or Love and Work: Does Business Owner Compulsion to Work Pay Off?” indicated that

female owners were less likely to be workaholics than male owners. In this study, workaholism was defined not by the number of hours worked, but by a set of behaviors that drive a business owner to work. This study found gender difference in workaholism among small business owners, suggesting that gendered specialization of household and childcare tasks continued to benefit men. Therefore, women may not only experience a marriage tax in terms of lower income, but also may experience a higher tendency to be workaholics if these female business owners are the primary source of household income.

- The findings from “Give, Sell, or Liquidate: The Effect of Socioemotional Wealth on Small Business Owner Exit Intentions” indicated that business owners with high socioemotional wealth were more likely to give or sell their businesses rather than liquidate. BIPOC (Black, Indigenous, and People of Color) business owners were also more likely to give or sell their businesses rather than liquidate compared to their White counterparts. The findings of this study also suggest that family business owners were more likely to give or sell their businesses to family than to sell to outsiders or liquidate. The findings of this study imply that family and non-family small business owners with high socioemotional wealth would choose exit strategies that preserve the continued existence of the firm. Understanding many different paths to exit the businesses among small business owners are important. Thus, the findings of this study further imply a need for strategic succession planning process such as identifying key business areas and positions, finding out the potential candidates, or developing and implementing succession strategies among small business owners.

- As for the study titled, “Succession Planning Expectations among Women-Owned Small Businesses”, we looked at how succession planning expectations differed by gender. We found that women owners were more likely to expect to give their businesses to family successors compared to men owners, whereas men owners were much more likely to sell their businesses to family successors than women owners. These findings can help prompt more research into understanding why these differences between men and women exist and whether there are underlying differences in their values or perceptions that drive these differences.

- For the study titled, “Social Media Use and Business Profitability Among Small Businesses,” we examined the role of social media in small businesses. The findings suggest that business owners who reported their company’s use of social media as important to the success of their business were more likely to report higher levels of business profitability. Increasing our understanding of the connections between social media and business success can help us provide practical suggestions for small business owners to help them better navigate decisions regarding how to employ social media in their business strategies.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Small Business Owners, Small Business Consultants, Small Business Financial Advisors, Business Succession Consultants, Small Business Researchers, Government Agencies, and Business and Economics Academics

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

There have been no major changes that have impacted my research plan.

Training and Professional Development:

My undergraduate research assistant (Mia Anderson) and graduate research assistants (Heather Kelley and Jennifer Whitely) have benefited greatly from being involved in the UAES 1621 project. These students have been exposed to important issues related to family-owned businesses through these training activities. They have had opportunities to be involved in all stages of the research process, from conducting literature reviews to writing up manuscripts and presenting at national conferences.

Dissemination:

First, two manuscripts were submitted in various journals. The first manuscript titled, “Work-Family Balance and Perceived Business Outcomes Among Copreneurial and Noncopreneurial Small Business Owners,” was submitted to the *Journal of Family and Economic Issues*. The second manuscript titled, “Love of Work or Love and Work: Does Small Business Owner Compulsion to Work Pay Off?” was submitted, but rejected by the *Journal of Small Business Management*. We will revise and resubmit this manuscript to the *Entrepreneurial Research Journal* in Spring 2023.

Lee, Y., Kelley, H., Wiatt, R., & Marshall, M. (Submitted). Work-family balance and business and profitability among copreneurial and noncopreneurial small business owners. *Journal of Family and Economic Issues*.

Wiatt, R., & Marshall, M., & **Lee, Y.** (Revising for resubmission). Love of work of love and work: Does small business owner compulsion to work pay off? *Entrepreneurial Research Journal*.

Secondly, three small articles were published through outlets of Purdue University. The first two were both published in the Summer 2022 *Quarterly Newsletter* at the *Purdue Institute of Family Business (PIFB)*. The third article was published in the Fall 2022 *Quarterly Newsletter* at the *Purdue Institute of Family Business (PIFB)*.

Lee, Y., Kelley, H., Wiatt, R.D., and Marshall, M. (2022). Succession planning expectations among women-owned small businesses. Purdue Institute for Family Businesses [PIFB] Quarterly Newsletter: 2022 Summer Edition (Special Research Edition). <https://ag.purdue.edu/agecon/fambiz/>

Lee, Y., Kelley, H., Wiatt, R.D., and Marshall, M. (2022). Social media use and business profitability among small businesses. Purdue Institute for Family Businesses [PIFB] Quarterly Newsletter: 2022 Summer Edition (Special Research Edition). <https://ag.purdue.edu/agecon/fambiz/>

Wiatt, R.D., Marshall, M., and **Lee, Y.** (2022). Pros and cons of being a workaholic. Purdue Institute for Family Businesses [PIFB] Quarterly Newsletter: 2022 Fall Edition. <https://ag.purdue.edu/agecon/fambiz/>

Lastly, two research presentations will be presented in a paper session at the *United States Association for Small Business and Entrepreneurship (USASBE)* Conference in January 2023 and will be published in the proceedings of USASBE.

Marshall, M., Wiatt, R., **Lee, Y.**, Cheang, M., Valdivia, C., Haynes, G., & Doty, K. (2023). Use of family business adjustment strategies during COVID: A comparison between homebased and non-homebased businesses. Submitted to Emerging Research Papers section for the 2023 USASBE Conference.

Wiatt, R., Marshall, M., Haynes, G., & **Lee, Y.** (2022). Small businesses during COVID-19: Funding strategies expedite recovery and minimize income loss? Submitted to Emerging Research Papers section for the 2023 USASBE Conference.

Plan of Work:

- I plan to develop “Social Media Use and Business Profitability Among Small Businesses,” which was previously published as a brief report in the *PIFB Quarterly Newsletter*, into a full length, peer-reviewed journal article. We (**Lee, Y.**, Kelley, H., Wiatt, R.D., & Marshall, M.) plan to submit this manuscript to the *Journal of Small Business & Entrepreneurship* in 2023.
- I plan to develop “Succession Planning Expectations Among Women-Owned Small Businesses,” which was previously published as a brief report in the *PIFB Quarterly Newsletter*, into a full length, peer-reviewed journal article. We (**Lee, Y.**, Kelley, H., Wiatt, R.D., & Marshall, M.) plan to submit this manuscript to *Women in Business and Entrepreneurship* in 2023.
- I plan to assist my colleagues (Wiatt, R., Marshall, M., Haynes, G., & **Lee, Y.**) in the preparation of “In the Depths of Despair: Lost Income and Recovery for Small Businesses During COVID-19,” for publication in the *Journal of Contingencies and Crisis Management* in 2023.
- For the research project titled, “Use of Family Business Adjustment Strategies During COVID: A Comparison Between

Homebased and Non-Homebased Businesses,” I plan to work with colleagues (Marshall, M., Wiatt, R., **Lee, Y.**, Cheang, M., Valdivia, C., Haynes, G., & Doty, K.) to convert this presentation into a peer-reviewed journal article. We plan to submit this manuscript to the *Journal of Family Business Strategy* in 2023.

- I also plan to work with colleagues (Haynes, G., Wiatt, R., Marshall, M., & **Lee, Y.**) to convert “Small Businesses During COVID-19: Funding Strategies Expedite Recovery and Minimize Income Loss?” into a peer-reviewed journal article. The journal we plan to submit to will be determined in the future.

- I am currently working on a research idea with other members of the NC1030 working group (Melody Lehew, Kelsie Doty, and Sonali Diddi). We are beginning work on a number of new projects that aim to increase understanding of sustainability and resiliency among Small to Medium size Enterprises (SMEs). Specifically, our future research products will focus on investigating how business practices transform into sustainable and resilient systems that can support a regenerative fiber and food system that enhances the well-being of families, communities, and eco-systems. This will be an important focus for the next four years.

Assessment of Money Scripts and Money Disorders Among Millennial College Students

Project Director

Lucy Delgadillo

Organization

Utah State University

Accession Number

1012904



ASSESSMENT OF MONEY SCRIPTS AND MONEY BIASES AMONG MILLENNIAL COLLEGE STUDENTS

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

1. Identify how prevalent money scripts and money biases are among millennial college students, and what demographic factors are associated with money scripts and money biases.
2. Make the case for the inclusion of interior finances in current high school and college curriculum by sharing the results of this study with different stakeholders, including instructors who train family and consumer sciences education students and family finance students, as well as Utah State Board of Education Financial Literacy representatives.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

The primary goals for this project were:

- (a) understand the prevalence (or lack of) money scripts and money disorders among millennials college students in Utah
- (b) make a case for the inclusion of interior finances in the current high school and college curriculum by sharing the results of this study with different stakeholders, including instructors who train family and consumer sciences education students and family finance students, as well as the Utah State Board of Education Financial Literacy representatives.

The most significant impact of this research was the opportunity to introduce change in knowledge and action in how we teach Financial Literacy to both high school and college students in Utah. One meta-analysis study on financial Literacy showed that the impact of financial education on behavior varies with how much financial education people receive and when they get it (timing is of the essence). The closer the intervention is to the financial decision, the more effective it becomes (NEFE, 2014). Juniors and seniors in high school and first-year students in college will encounter myriad financial decisions. The closer the intervention is to such decisions, the better the choices they will make, and the better the chances that these decisions will positively influence family and societal well-being.

As a result of using the AES project UTA-1350 as seed money, I was able to secure a grant from the Utah State Board of Education (USBE) in 2018. The USBE grant served to develop a new class, FCSE 1350 Financial Literacy, which would be a USU

BSS class and offered as concurrent enrollment. FCSE 1350 teaches financial literacy from a social sciences perspective which is different than teaching a personal financial literacy class from the business perspective. The business model emphasizes economic literacy on the numerical part of finances (exterior finances). A business personal finance course focuses on reaching an optimal individual decision-making model. The business model leaves out the behavioral and emotional components of money. The business model assumes that we are rational human beings making optimal individual financial choices with perfect information and in an isolated fashion. We now know that is not true.

One key finding of the UTA-1350 research is that money scripts and biases, which are transgenerational psychological beliefs about money usually developed in childhood, are ubiquitous in the Utah population. Based on the finding of this research, the new FCSE 1350 course includes two modules that expose students to learning these concepts. High schools and college students in Utah are now learning to identify how these preconceived beliefs about money drive adult financial outcomes, behaviors, and other components of economic well-being. Students are also learning to appraise how money relationships are embedded into culturally and ideologically determined social and political structures.

Financial Literacy recognizes that individual financial well-being cannot be entirely separated from the way we think about money. Our financial well-being affects and is affected by our money scripts and biases, which in turn are dictated by the local community, the nation, and even global activities.

Briefly describe how your target audience benefited from your project's activities.

The main audiences are millennial college students, family finance and family and consumer sciences educators at the high school level, and financial literacy educators and counselors at the university, state and national levels.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Nothing to report.

Training and Professional Development:

This project provided several opportunities for training professionals who teach financial Literacy, namely teachers and financial counselors. I did a total of 25 training activities. They include creating a website, 15 one-on-one mentoring sessions with high school teachers teaching financial literacy, one sponsored thesis, one state-level workshop on financial literacy for family and consumer sciences teachers, one USU webinar for financial practitioners who work in the USU Money Management Center, and seven national conference presentations. Details of these training opportunities are below:

Website on Financial Literacy for Family and Consumer Sciences Education Teachers

My graduate student Amber Williams and I created a website, <https://caas.usu.edu/fcse/training>, for FCSE high school teachers who teach Financial Literacy, or Adult Roles and General Financial Literacy, in Utah. The website includes a video interview in which I explain the need to connect social sciences and financial literacy. The website also provides examples of how to align the financial literacy content with the Utah State Board of Education Strands and Standards' respective learning outcomes and other additional resources for FCSE teachers. In addition, the training video explains the importance of adding a couple of modules on money scripts and behaviors and talking about the emotional aspects of money.

One-on-one training opportunities

During the school year 2020-2021 and 2021-2022, I personally observed and provided one-on-one guidance to 15 teachers in the State of Utah teaching financial Literacy as concurrent enrollment. These 15 teachers come from Emery High School (HS), Mountain Crest HS, Ridgeline High School, Logan High School, Green Canyon High School, Sky View High School, Box Elder High School, and Bear River High School.

A goal for 2020 was to sponsor a thesis on financial literacy in the secondary setting. My graduate student, Jennifer L. Gardner, successfully defended her thesis on November 16, 2021. The title of her thesis is, Evaluating Parental Involvement in Required High School Financial Literacy Courses Taught in Utah Schools. <https://digitalcommons.usu.edu/etd/8380>

State-level Workshop on Financial Literacy for Family and Consumer Sciences Education Teachers

In May 2021, I did a presentation/training to 25 attendees to explain how to include the affective components of money in the FCSE 1350 Financial Literacy Concurrent Enrollment Course. Utah State Board of Education sponsored the conference. Here is the link to the presentation, <https://screencast-o-matic.com/watch/crhtbjVhLCX>

Training on Financial Literacy for Financial Counselors.

I did a 90-minute training for the nine financial counselors and educators of the USU Student Money Management Center <https://www.usu.edu/smmc/>. I explained what money scripts and biases are and how we can help clients overcome their biases. The training expanded the attendee's knowledge of four emotional biases (loss aversion, overconfidence, endowment, and status quo) and four cognitive biases (conservatism, hindsight, anchoring and adjustment, and mental accounting)—the webinar trained practitioners on intentionally using financial biases to increase the impact and success of financial interventions.

National Conference Presentations

Delgadillo, L., Abbott, E., "Why is Saving Money so Much Harder?", 2021 AFCPE National Conference, AFCPE. November 2021. Peer-reviewed/refereed, AES:

Delgadillo, L., "Inclusion of Affective Knowledge in a Financial Literacy Class", 2021 Utah FCS Summer Conference, USBE, Virtual. June 2021. AES:

Delgadillo, L. "Effective Strategies to Identify and Mitigate Emotional and Cognitive Biases", Association of Financial Counseling, Planning and Education, Virtual. November 18, 2020. Contributed (refereed), Peer-reviewed/refereed, AES: Stokes, C. (Presenter & Author), Delgadillo, L., "Group Coaching for Millennials", AFCPE Annual Conference, Portland, Oregon. November 19, 2019 - November 21, 2019. Contributed (refereed), AES:

Williams, A. (Presenter & Author), Delgadillo, L. (Presenter & Author), "Money & Society", FCS Summer Conference, Utah State Board of Education, West Lake High School, Saratoga Springs, UT. June 12, 2019. AES:

Delgadillo, L. "Emotional aspects of Money", American Association of Family and Consumer Sciences, Atlanta, Georgia. June 24, 2018 to June 27, 2018. Contributed (refereed), AES:

Delgadillo, L. (Presenter & Author), Stokes, C., "Effective coaching models for structuring financial coaching sessions", AFCPE Annual Conference, Portland, Oregon. November 19, 2019 - November 21, 2019. Contributed (refereed), Peer-reviewed/refereed, AES:

Dissemination:

As part of the dissemination process, I had one published book chapter, three refereed journal articles, three conference proceedings, one website, and one additional journal article to be submitted in August 2022 to the Journal of Extension. In addition, some of the training activities described above were also dissemination channels.

Book Chapter

Delgadillo, L., & Law, R. (2018). Personal Finance Competencies in the Context of the Practice of Financial Counseling. Financial Counseling. Springer Nature.

Refereed Journal Articles

Delgadillo, L. (2022). Using Wlodkowski's model to enhance motivation to learn financial education. *Journal of Family and Consumer Sciences* 114 (2), 51-55. <https://doi.org/10.14307/JFCS114.2.49>

Delgadillo, L. (2021). Investigating Financial Biases that Can Increase Impact on Paying Bills and Saving. *Journal of Financial Therapy* 12 (2), 116-135. <https://doi.org/10.4148/1944-9771.1267>

Delgadillo, L., & Lee, Y. (2021). Association between financial education, affective and cognitive financial knowledge, and financial behavior. *Family and Consumer Sciences Research Journal* 50 (1), 59-75. <https://doi.org/10.1111/fcsr.12414>

Conference Proceedings

Delgadillo, L., Abbott, E. (2021). Why is saving money so much harder in practice and how financial biases can help? 2021

Delgadillo, L., Abbott, E. (2020). Effective Strategies to Identify and Mitigate Financial Biases. (pp. 29-30). AAFPCPE Conference Proceedings.

Stokes, C., Delgadillo, L., Lee, Y. G. (2019). Group coaching for millennials. (vol. 64). Proceedings of the Association for Financial Counseling and Planning Education Annual Conference.

Website for FCSE high school teachers:

Williams, A., & Delgadillo, L. (2020). Financial Literacy FCSE 1350. <https://caas.usu.edu/fcse/training>

Research Currently Under Review:

Delgadillo, L. & Erickson, L. (2022). Overspending, financial infidelity and financial enabling negatively affect paying bills on time and saving. *Journal of Extension*.

Plan of Work:

1. Successfully submit the article to the Journal of Extension.
2. Continue training high school teachers, and USU students on the importance of incorporating money biases and money scripts in their practices.
3. Update the website with current resources.

Individual and Family Resource Management

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7000398



Celebrating Women

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

According to the World Health Organization (WHO), mental health is not avoidance of mental illness, but rather it is a state of overall wellness that includes the ability to manage stress and live productively. Mental health concerns such as anxiety and depression often disproportionately affect women. In Utah in 2017, 32% of women ages 18-34, 21% of women ages 35-49, and 19% of women ages 50-64 reported poor mental health for at least one week out of the previous month in comparison to 20%, 12%, and 10% of men in these age groups respectively. Wellness includes multiple components such as physical, environmental, social, emotional, and financial aspects. It also includes the cultivation of skills such as problem-solving, stress management, positivity, maintaining balance, and social connection.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In response, USU Extension hosts the Celebrating Women Conference which addressed various aspects of wellness: mental wellness, financial wellness, stress management, positivity, and cultivating balance, while providing opportunities for women to connect with one another. The annual event has grown consistently since it began in 2018. Designed as an event to promote wellness and balance in the lives of women across the state, the conference features workshops presented by experts. Workshops include such topics as positive body image, self-care, and self-confidence.

Briefly describe how your target audience benefited from your project's activities.

E. Parkhurst reported the evaluation results of the 2022 Celebrating Women Conference. Findings from a sample of 162 participants (n = 162) showed 100% of respondents were either extremely likely or likely to make a positive change as a result of participating in the conference, such as prioritizing their time, setting boundaries, asking for help, changing their mindset,

practice intuitive eating, speaking and being kinder to themselves or adjust their mental attitude. Most participants (93%) agreed the conference gave them strategies to improve their life, 93% agreed they want to make positive changes to their life, and 93% agree they expect that what they have learned will benefit their well-being.

The conference team also evaluated major conference sessions. After participating in “Healing Disordered Relationships with Food & Body through Intuitive Eating,” 81% agreed “I know how to identify and define diet culture,” 100% agreed “I know how to use the intuitive eating framework,” and “I plan to make positive changes based on what I learned in this session.” After participating in “Living Life Well-Rounded,” 100% agreed “I know how to determine what matters most in my life,” “I know how to create my own version of living well-rounded,” and “I plan to make positive changes based on what I learned in this session.” After participating in “How Women Can Use Their Voices to Stand up for Themselves or Others,” 100% agreed “I know how to find my own voice,” “I know how to stand up for myself,” and “I plan to make positive changes based on what I learned in this session.” After participating in “Self-Care is Self-Survival,” 88% agreed “I know the purpose of self-care,” 87% agreed “I know ways to self-regulate,” and 88% agreed “I plan to make positive changes based on what I learned in this session.” After participating in “Positive Body Image for All Bodies,” 86% agreed “I know what contributes to negative body image,” 100% agreed “I know ways to help myself feel better about my body,” and “I plan to make positive changes based on what I learned in this session.” Lastly, after participating in “How to Step out of Your Comfort Zone and into Nature,” 100% agreed “I know the benefits of being active outside,” “I know how to step outside of my comfort zone,” and “I plan to make positive changes based on what I learned in this session.”

Briefly describe how the broader public benefited from your project's activities.

The Celebrating Women Conference addressed various aspects of wellness: financial wellness, stress management, positivity, and cultivating balance. It also provided opportunities for women to connect with one another. The conference directly addresses persistent issues affecting women and facilitated a positive environment for shared experiences, learning, and empowerment. With yearly increases in participation, USU Extension expects the conference to directly impact the wellbeing of women across the state.



Family Finance Education

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Research shows only 49% of Americans could afford a \$1,000 unexpected expense. That percentage dropped to 41% during the COVID-19 pandemic. This issue is exacerbated by the high costs of housing, high-level debt compared to income, and stalled income growth due to sluggish economic growth during the last two decades. Results from the National Endowment for Financial Education (NEFE) showed 84% of residents are stressed about finances, and more people are tapping into savings and investments, deferring bill/debt payments, and taking on more credit card debt.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In response, A. Christensen and team facilitated train-the-trainer events on finance education to 54 Extension faculty/staff and community leaders in Utah. The multiplier effect of the train-the-trainer program can significantly impact residents' access to personal and family finance education in Utah. In 2022, Christensen facilitated a financial management Book Club with virtual meetings, weekly webinars, and in-person classes on personal financial management.

Briefly describe how your target audience benefited from your project's activities.

For the Book Club (n = 12), 91% of participants agreed they had a better understanding of personal financial management, and 100% agreed they would make positive changes to their personal financial management strategies. When asked what behavior they would change as a result of attending, participants said, “I will act on ideas and sources of additional income or flows of money. I will continue to heal past fears, blame, and perceived pain in my life caused by money or the lack thereof. I will use some of my additional income to save and/or invest,” “As a result of participating in the 30-Day Money Cleanse Book Club I have learned to speak to myself more kindly regarding money. I have learned to align my money and my values. I am in the process of tidying up my money outlook and it feels good,” “For many years, my mindset was one of scarcity. I will focus more on having enough instead of worrying about scarcity,” and “I am going to share this book with my husband so we can read it and work through it together. I think it is a great couple share to help with our finance management.”

For the Weekly Webinars on personal financial management, evaluation results from a sample of participants ($n = 500$) indicated 93% demonstrated an improved understanding of financial wellness, and 96% intend to make positive changes to their personal finance practices. When asked what behavior they would change as a result of attending select participants said, "I got my credit report and will check my credit score for the first time ever," "I will talk to my husband about his and my financial goals and write down some goals," "Having completed our estate planning over 15 years ago, this course was just the kick we needed to relook and update our will and advance directive," "Start a revolving savings acct or finally open an IRA. I am going to go through the cutting expense guidebook for some step-down ideas to lessen my expenses," "I am going to start paying myself first, because I have always paid myself last," "One of my biggest takeaways was accepting what you spent and not having guilt of spending more. I'm going to positive talk to myself that what I gave is enough," and "I am going to unsubscribe from all my sales texts and automate my savings deposits."

Briefly describe how the broader public benefited from your project's activities.

The family finance series are important to helping families cope with hardship and economic uncertainty.



Fatherhood Education

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Led by B. Higginbotham, Utah State University (USU) Extension administered the *Healthy Relationships Utah (HRU)* initiative, which includes relationship education programs for fathers. Restrictions stemming from the COVID-19 pandemic required the transition from in-person to virtual workshops for all fatherhood education programs and for other *HRU* services statewide (Higginbotham et al., 2021). In recent years, scholars have explored the feasibility and impact of online intervention (Doss et al., 2019; Duncan et al., 2009) as a tool to disseminate relationship education. Overall, findings on online interventions have been mostly positive (Roddy et al., 2018). To explore the impact of the transition of fatherhood education to online delivery, we examined differences in outcomes among fathers in communities across the state, using both quantitative and qualitative methods.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Fatherhood education is effective in increasing father involvement, improving coparenting, and increasing job skills (Holmes et al., 2020). With past research focusing more on the experiences of middle-class, European Americans (Skogrand et al. 2009), an emphasis has been placed on increasing participation among fathers from historically underrepresented groups (Avellar et al., 2018). Some scholars suggest that virtual formats may help reach underrepresented groups with more ease and less expense to the participant and program itself (Townley & Yalowich, 2015). The transition to virtual workshops allowed the project team to examine the possible differences in outcomes between in-person and virtual formats, while also learning more about potential differences in processes between these formats by qualitatively examining the experiences of virtual participants who completed a fatherhood education program.

Participants were taught the *24/7 Dad HRU* program in four, two-hour sessions by trained facilitators, which is consistent with program procedures for in-person sessions. The primary change to the program delivery was that participants met in virtual classrooms through Zoom. A pretest-posttest design evaluated whether participants increased their knowledge of father-child closeness and job skill development, comparing delivery formats (in-person vs. virtual). Qualitative data provided insight on the experiences of virtual participants, by asking them what they liked most and liked least about the virtual workshop.

Briefly describe how your target audience benefited from your project's activities.

With respect to outcomes related to knowledge change, paired-samples *t*-tests revealed statistically significant increases in knowledge from pretest to posttest for father-child closeness ($p < .05$) and job skill development ($p < .05$). Increases were greatest for father-child closeness ($MD = 0.11$; $SD\epsilon = 0.35$; $d = 0.23$). Increases for job skill development were comparable ($MD = 0.09$; $SD\epsilon = 0.44$; $d = 0.18$). For differences in knowledge gain between in-person and virtual participants, independent samples *t*-tests revealed no statistically significant differences between in-person and virtual format participants from pretest to posttest. Therefore, in-person and virtual participants experienced similar levels of knowledge improvements from the program.

Qualitative data were used to describe virtual participants' experiences. Participants specifically mentioned liking the virtual format, noting the convenience of distance learning and features of virtual formats like breakout sessions. However, most participants reserved their comments for the quality of the virtual workshop and facilitator effectiveness. For example, one participant noted, "I really enjoyed feeling more capable and prepared to be a father from what I learned in the class." Another participant stated, "The teachers had really excellent ways of communicating the concepts to real world situations and made it fun and enjoyable to attend."

Some participants described their experience as less positive because of the virtual format. For example, the lack of intimacy in virtual workshops was described, "I'll be honest, the digital Zoom course was a little difficult and limited interaction." Others noted technical difficulties, "It was online so the sound quality was not always the best." Despite disliking the format, participants were also understanding of the circumstances under which workshops were being held, "Doing this remotely rather than in person, although this isn't necessarily a reflection on the course itself. This is just the way it is, given the circumstances."

Briefly describe how the broader public benefited from your project's activities.

For *HRU*, adjustments centered on the transition from in-person to virtual classrooms. On average, virtual formats attracted fathers who were more educated and financially affluent when compared to fathers who completed the in-person format, suggesting that the transition to virtual delivery may decrease program usage by underrepresented groups. Quantitative data showed no significant differences in program outcomes by format, and fathers in both in-person and virtual workshops reported benefits on targeted outcomes related to father-child closeness and job skill development. Qualitative responses underscore benefits as well as elements of convenience, but were mixed in terms of participant perceptions toward virtual programming, also illustrating the challenges associated with virtual delivery methods.

These findings provide support for the effectiveness of the *24/7 Dad* program, regardless of delivery method. They also illustrate the ability of Extension programs to adapt and meet community needs. The findings suggest adopting a dual-delivery approach to future fatherhood education programming inasmuch as some participants may prefer one format over the other. Providing fatherhood education in both virtual and in-person modalities could increase the accessibility of Extension programming for fathers across Utah who have different learning preferences or those who may face specific barriers to in-person participation.



Homebuyer Education

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Homeownership has been linked to improved financial benefits for a household, lower rates of crime, and increased civic participation within communities. However, homeownership depends on income, credit rating, monthly expenses, down payment, and interest rates. First-time homebuyers are particularly in need of financial and housing education to prepare them for a home purchase.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The USU Extension Homebuyer Education courses are HUD-approved and USDA Rural Housing approved; both courses meet the research-based National Industry Standards for Homeownership Education and Counseling and the HUD guidelines for Homebuyer Education. The Online homebuyer education course is hosted online in English and Spanish. Between 2020 and 2022, there were 1384 participants in the English Course and 15 participants in the Spanish course.

Briefly describe how your target audience benefited from your project's activities.

After completing the homebuyer course, M. Jewkes reported the percentage of participants who planned to implement recommended practices when buying their homes; 82% established emergency savings, 86% utilized the revolving savings strategy, 86% saved 1% of the home's value per year for repairs, 43% identified an affordable mortgage payment, 33% implemented a budgeting method, 31% reduced expenses, 29% reduced debt, 34% requested a free credit report, 37% fix errors on their credit report, 53% shopped for a competitive interest rate, and 71% reviewed their loan estimate and closing disclosure. In addition, a follow-up survey indicated 50% of participants in the homebuyer course had "a great deal" or had "a lot" of importance in their success in purchasing a home. When asked about their experiences in the course, participants said,

“It significantly expanded my understanding of the home buying process and I feel more confident about it now,” “It has taught me a lot about budgeting, saving, and if my home is in foreclosure then there are steps to help me out,” “This course has helped me become more familiar with loan options to be aware of how to prepare and make this as affordable as possible,” and “I feel very empowered from the content provided to know what to look for and what to look out for in every segment of the home buying process.”

Briefly describe how the broader public benefited from your project's activities.

With increasing interest rates and economic slowdown, the homebuyer course provides residents with valuable support to help them navigate uncertain times when purchasing a home.



Strengthening Marital Relationships

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

The Utah Marriage Commission (UMC) has provided relationship and marriage resources to Utahns for over two decades. Originating through the Utah Governor's office in 1998, the Utah State Legislature moved commission oversight and hosting to Utah State University in 2021. The UMC's mission is to help Utah residents form and sustain healthy, enduring marriages and relationships through education, classes, conferences, and other resources. It specializes in serving populations at higher risk for family instability.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

D. Schramm and B. Higginbotham provide leadership as USU hosts the commission and manage the Temporary Assistance for Needy Families. This includes Bi-weekly webinars from relationship and marriage experts on a variety of topics. RELATE is an in-depth relationship assessment that offers a comprehensive report on how couples view their relationship. With over 40 years of research, RELATE is a helpful resource for people to evaluate and better understand their relationships. ePREP, a 6-hour marriage preparation online course, is designed to help couples improve their relationship through principles and skills. Upon completion of the course, couples qualify for the Marriage Education Discount of \$20 off their marriage license.

Briefly describe how your target audience benefited from your project's activities.

Evaluation results indicated that more than 96% of webinar respondents agreed on the following questions:

- Because of things I learned from the webinar, I have more knowledge/skills related to healthy relationships.
- Because of the things I learned from the webinar, I am more committed to forming/maintaining healthy relationships.
- Because of the things I learned from the webinar, I have more knowledge/ability to recognize unhealthy relationships.

Comments from webinar participants included, “The speaker explained a lot of information that I didn't know before. It was very helpful,” “I so appreciate you providing these webinars! I've watched many that are very good,” “I thought the presenter did an amazing job talking about hard topics that most people don't talk about she did an excellent job,” “This was good information. We need more information on how to apply it in our marriage of 44+ years,” and “Very well done in a compassionate & nurturing manner for an often-difficult subject.”

For the RELATE assessment, participants' comments included, “Very well done in a compassionate & nurturing manner for an often-difficult subject,” and “I Needed relationship understanding and advice,” From ePREP participants, when asked why they took the course, some comments were, “To build a stronger relationship before we get married,” “To better my relationship with my wife,” and “To learn more about what is a healthy relationship and to ensure that me and my partner to have a better understanding about love.”

Briefly describe how the broader public benefited from your project's activities.

This program contributes to family stability, which addresses several priority needs such as emotional and mental wellbeing. In 2022, USU Extension made progress in improving marital relationships in Utah.



Wellness Walks

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

A needs assessment completed by the Davis County Health Department group, Davis4Health, found that the leading health concerns crosscutting most age groups are healthy eating, inactivity, obesity, and mental health. The main health concerns for children included physical activity/healthy eating, and for adults included obesity and mental health.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

In response, E. Parkhurst provided a health and wellness program in 2022 that focused on holistic wellness. In addition to healthy eating workshops, the program included a Wellness Walk. Research found that the frequency of greenspace use was associated with increased levels of self-esteem, life satisfaction, and happiness, and decreased levels of depression, anxiety, and loneliness. According to the County Health Rankings, obesity and social associations are two areas of improvement for Davis County. In response, E. Parkhurst started the Wellness Walks on the first Saturday of every month at the USU Extension Botanical Center Pond trails. The purpose was to provide an opportunity for free physical activity, provide an opportunity for nurturing social connections, and to improve knowledge of health and wellness.

Briefly describe how your target audience benefited from your project's activities.

Evaluation results indicated almost all participants (90% to 100%) agreed they felt like their physical and emotional well-being has improved after attending the Wellness Walks. In addition, almost all participants stated they felt more connected to nature, felt a greater sense of gratitude, and had a greater sense of mindfulness. One participant said, "This walk is such an amazing opportunity to get moving as a family. I can't wait to bring [friend] to the next one and go fishing afterward."

Briefly describe how the broader public benefited from your project's activities.

The wellness walks encourages community capacity building and facilitates bonds between friends, family, and neighbors.

Critical Issue

Nutrition and Health

Agriculture-Health Nexus: Linking Plant, Animal, and Human Health in Food Systems

Project Director

Stephan Van Vliet

Organization

Utah State University

Accession Number

7002839



Agriculture-Health Nexus: Linking Plant, Animal, and Human Health in Food Systems

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Food systems are facing the following grand challenges: a growing population with metabolic health issues; climate change and pressure on ecosystems; and nutrient adequacy and safety (Godfray et al., 2018; Willett et al., 2019; van Vliet et al., 2020). We currently use over a third of the Earth's land surface and over 75% of the world's freshwater supply for food production (Brondizio et al., 2019). Moreover, food production is considered an important contributor to climate change (IPCC, 2019). Compounding the challenge is the growing number of individuals with metabolic disease, with unhealthy diets considered as a leading cause (Vos et al., 2020).

In response to these challenges, farmers, non-governmental organization (NGOs), and federal agencies (e.g., USDA) have expressed a need to understand and implement sustainable production practices that have the potential to improve both environmental and human health (FAO, 2019; Finley and Fukagawa, 2019; IPCC, 2019). Promising agroecological (sustainable) farming practices include multi-cropping, ley rotations, integrated crop-livestock systems, and/or adaptive grazing of livestock (Wezel et al., 2014; Kronberg et al., 2021) (Fig. 1). When properly implemented, such practices can improve soil health (McDaniel et al., 2014; Albizua et al., 2015), nutrient cycling (Kronberg et al., 2021), and biodiversity above and below ground (Wezel et al., 2014). Despite potential major ecological benefits, we lack *critical knowledge* if practices that improve sustainability also have potential to benefit the foods quality and human health.

The goal of my research program is to systematically define linkages between sustainable agriculture systems, the nutrient quality of foods, and human health. *My research group studies shared metabolites and nutrients along the plant-animal-human health continuum in food systems to investigate if increased plant quality and animal health, beneficially impacts the nutrients in foods and human health responses.*

Year 2022 Milestones:

- Collect forage/food samples for USDA-NIFA-SARE LS 21-455
- Analyze meat/forage samples for USDA-NIFA-SARE LS21-357
- Start RCT for LS-21-357
- Start RCT for Agro-ecology Health Study
- Finish Turner Bison data analysis/manuscript
- Collect beef samples from 50 farmers for Beef Nutrient Density project
- Perform metabolomics on chicken samples for Purdue Farms
- Present data at ITF, Northeast Pasture Conference, Advances in Food and Beverage Analysis, Carnecorp (Chile) and others
- USDA and industry grant submissions

Year 2023 Milestones:

- Collect forage/food samples for USDA-NIFA-SARE LS 21-455
- Perform food/forage sample analysis for Agro-ecology Health Study
- Continue with year two of RCT for Agro-ecology Health Study
- Finish RCT for LS-21-357
- Collect beef samples from 75 farmers for Beef Nutrient Density project
- Publish pilot data on beef and chicken metabolomics
- Present data at Grassland Congress, USDA Northern Great Plains Conference, and Amazing Grazing
- USDA and industry grant submissions

Year 2024 Milestones:

- Finish RCT for USDA-NIFA-SARE LS 21-455
- Analyze human urine/plasma samples for USDA-NIFA-SARE LS21-357
- Publish Agro-ecology Health Study food metabolomics work
- Perform Bison meat metabolomics trials
- Collect beef samples from 75 farmers for Beef Nutrient Density project
- Present at 4-5 conferences
- USDA and industry grant submissions

Year 2025 Milestones:

- Analyze USDA-NIFA-SARE LS 21-455
- Publish Agro-ecology Health Study human nutrition metabolomics work
- Publish Bison meat metabolomics trials
- Collect beef samples from 75 farmers for Beef Nutrient Density project
- Present at 4-5 conferences
- USDA and industry grant submissions

Year 2026 Milestones:

- Publish final findings USDA-NIFA-SARE LS 21-455
- Finish beef nutrient density project
- Present at 4-5 conferences
- USDA and industry grant submissions

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

1. Major objectives completed:

- Started two randomized controlled human feeding trials (one 14-week trial and one postprandial trial with three different visits). We have completed 16 participants for the long-term trial and 6 participants for the short term feeding trial so far. Both trials will be completed next year.
- Contributed to obtaining funding and purchasing an LC/MS-MS as a Core service in CIB.
- Obtained >\$1.0 million in research grants since starting at USU in January 2022.
- Published 4 papers with a USU affiliation this year.
- Obtained soil, forage, and plant samples from 50+ farmers for profiling.

2. Specific objectives met:

Objective 1: Characterize metrics of plant diversity, soil health, and animal health in various (commercial) agro-ecological farms across the US (200+ farms over 5 years).

We have profiled 50+ cattle ranches this year; putting us on track for this objective. Initial findings will be published next year.

Objective 2: Probe >200 nutrients and biochemicals in food samples (meat, milk, and crop samples) using metabolomics approaches to gain insight into nutrient density.

We have profiled forage and meat samples from 50+ farms this year; putting us on track for this objective.

Objective 3: Perform randomized controlled trials with adults at risk of metabolic disease to determine the impact on food nutrient density on cardiovascular disease risk biomarkers.

Started two RCTs this year, and completed 20 research participants.

3. Major findings:

So far, we have found that increased plant diversity on pasture and phytochemical diversity of forages benefits animal health and welfare. We also found that this upcycles anti-oxidants and vitamins in meat and milk, thus improving their nutritional quality. We have also linked this to metrics of soil health and find that improvements in soil health underlie these benefits. We have performed this work in bison, chicken, and beef as part of ongoing projects. We are finding initial linkages between soil health, plant diversity, and animal metabolic health and the nutrient density of their products. Ongoing work will include studying whether this has an appreciable effect on human health. The systems work performed as part of these studies investigates whether more environmentally friendly production practices also have a benefit for animal and human health.

4. Key impacts or other accomplishments realized:

There is continued interest in this work and major food industry players have expressed interest in incorporating these findings in their sourcing and production practices, including Applegate LLC and the Turner Ranches.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audiences that were reached include scientists, policy makers, consumers, farmers, and food industry groups. Each product, described below, will indicate which target audience(s) were involved and how they have been reached.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No major changes/problems to report.

Training and Professional Development:

- One week LC/MS-MS training from Sciex to operate the new equipment in CIB.
- Attended the Chicago Council for Global Food Affairs conference on linking agriculture and human nutrition. This provided me with a networking opportunity to strengthen collaborations in this field.
- Tenure academy at Utah State University
- Participated and presented in the NDFS seminar series.

Dissemination:

- Presented work related to this project at 13 conferences/farmer workshops as part of invited talks to thousands of farmers, consumers, academics, and food industry representatives (see description above in *other products*)
- Published 4 papers related to this work in impactful journals such as Animal and the Journal of Animal Science and Biotechnology.
- I was interviewed in 10 podcasts reaching large numbers of consumers.
- Contributed to an FAO fact sheet and publication on livestock and human health: <https://www.fao.org/3/cc0946en/cc0946en.pdf>

Products:

Other Products:

Data and Research Material - As a panel member of a UN/FAO subcommittee on Agriculture, I contributed to the publication of the following report:

<https://www.fao.org/3/cb8424en/cb8424en.pdf>

<https://www.fao.org/3/cc0946en/cc0946en.pdf>

As the FAO has a wide reach, this work has been shared with policy makers, scientists, and food industry groups.

Audio or Video - **Dec. 2022. GPS Dairy Leaders Forum, Lake Mystic, WI.** Making the Soil Health – Human Health Connection in Livestock Systems. Invited talk to about 300 farmers/dairy industry representatives on work linking sustainable agricultural production systems with dairy nutrition.

Audio or Video - **Agilent Webinar Series.** Impossible to go Beyond Beef? Metabolomics Profiling of Plant-based Meat Alternatives. I provided a webinar to about 1500 people including academics and food industry groups on our metabolomics work of plant-based meat alternatives

Audio or Video - **Nov. 2022. Global Conference on Sustainable Beef, Denver, CO.** Balancing Production, Consumption and Nutritional Needs. Invited talk to about 500 academics, food industry groups, policy makers, and farmers on our work linking grazing practices in cattle to human nutrition and health.

Audio or Video - **Nov. 2022. Silver Fern Farms, New York, NY.** Linking Plant-Animal-Human Health in Livestock Production Systems. Invited talk to leaders of the New Zealand beef industry on our work that links the transfer of phytochemicals from forage to meat and its impact on human health.

Audio or Video - **Oct. 2022. Perdue Animal Care Summit, Salisbury, MD.** In Search of Superior Chicken: Linking Animal Welfare and Human Health. Invited talk at the Animal Health Care Summit organized by Perdue on work linking outdoor access and different feeding practices in chickens to animal welfare and human nutrition. This work also led to a grant by Perdue Food LLC.

Audio or Video - **Aug. 2022. Chilean Ministry of Agriculture and various Universities in Chile.** Red Meat, Human Health and Sustainability. Provided talks to academics, students, farmers, and policy makers as part of a series of four talks in Chile. I also got to present our work on sustainable grazing practices in cattle and human nutrition to Chilean government officials.

<https://www.youtube.com/watch?v=JGiOTi-X6to>

Audio or Video - **Aug. 2022. Bionutrient Institute Webinar.** Beef Nutrient Density Study Preliminary Results Webinar. Presented our initial findings of our beef nutrient density profiling study to interested farmers and consumers.

<https://www.youtube.com/watch?v=wEnDOmwa7qE&feature=youtu.be>

Audio or Video - **Aug. 2022. Green Cover Seed Webinar.** Presented findings on our work linking sustainable grazing practices to human nutrition and health to farmers and consumers.

<https://www.youtube.com/watch?v=6ZQ1r9jGdss>

Audio or Video - **Aug. 2022. AOAC International Meeting, Scottsdale, AZ.** Impossible to go beyond beef? Profiling food metabolomes of meat and a meat-replacement. Presented on our work on plant-based meat alternatives to academics and food industry.

Audio or Video - **July 2022. Global Food & Farm Online Community Webinar.** The effect of grazing practices on the nutritional composition of meat and milk. Presented to farmers and academics.

Audio or Video - **July 2022. IFT 2022. Chicago, IL.** How is our fundamental understanding of molecules such as proteins lipids or enzymes leading to innovations in food or beverages? Invited panel discussion on our work on plant-based meat alternatives.

Audio or Video - **February 2022. Northeastern Pasture Conference Webinar.** Webinar to farmers and academics on our work linking sustainable grazing practices to human nutrition.

<https://www.youtube.com/watch?v=9p-9MNnDjKQ>

Instruments or Equipment - Contributed to the purchase of a new LC/MS-MS at the Proteomics Core at CIB by obtaining to internal grants (UAES and Office of Research).

Physical Collections - Performed 15 on-site field days at regional farmers to collect forage, soil, and meat for our beef nutrient density project. Was send another samples from another 35 farmers that collected samples themselves through Standard Operation Procedures provided by our lab group.

Protocols - Started to randomized controlled trials where people are being fed foods from different agricultural production systems to evaluate human health effects. We have completed 25 participants this year.

Other - I was interviewed on 10 podcasts this year, which provided another avenue to disseminate findings to consumers.

Plan of Work:

- Profile 50 more farms and expand our work on sustainable ag and human nutrition to almonds, blueberries, and tomatoes.
- Complete our initial RCTs studying meat and produce from different production systems and their impact of biomarkers of human metabolic health.
- Publish our initial findings on bison and beef from different production systems in peer-reviewed journals.
- Seek additional external grants including industry and USDA funds (e.g., SARE)

Development of a Novel Sheep Model of Sickle Cell Disease

Project Director

Irina Polejaeva

Organization

Utah State University

Accession Number

7003083



In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Current treatments for Sickle Cell Disease (SCD) are not effective for all patients, and few patients qualify for the sole approved cure of a hematopoietic stem cell (HSC) transplant. Additional challenges exist in rural communities. With most (if not all) comprehensive SCD centers located in urban areas, there are treatment inequities for patients with SCD living in rural areas (Telfair et al. 2003). Development of novel gene and cell therapies, especially prenatally, are attractive and promising potential cures (Yawn et al. 2014) that would greatly benefit both urban and rural communities. However, to develop such therapies, animal models that accurately represent human anatomy and the patho-physiology of SCD are required, and the currently available mouse models are not ideal. The domestic sheep (*Ovis aries*) is a livestock model with numerous advantages, and it has previously been used as a translationally relevant model for a variety of human diseases, including inherited blood disorders such as hemophilia A (Porada & Almeida-Porada 2012). Importantly, this project contributes the development of genetic engineering techniques for small ruminants and these techniques will be broadly applicable for the production of genetically modified animals for food and fiber production. Furthermore, this project fits in with the one-health concept; drugs/therapies developing using this genetically engineered domestic animal model are likely to be adapted for use in veterinary medicine in the future.

Sickle Cell Disease (SCD), the most common inherited blood disorder, is caused by a point mutation in the HBB gene, which encodes the β -globin subunit of hemoglobin (Hb). The causative missense mutation in HBB induces a single amino acid change (Glu $\rightarrow$ Val) at the 6th position of the β -subunit of hemoglobin, leading to abnormal Hb polymerization and subsequent red blood cell (RBC) sickling, rigidity, and structural disruption. Such changes at the cellular level promote hemolysis, inflammation, and vasculopathy, causing a wide range of severe and life-threatening clinical manifestations (Rees et al. 2010). The sheep β -globin protein has high homology with the human protein, with ~86% amino acid sequence identity. Additionally, the human SCD mutation site is present in sheep HBB, suggesting that introduction of the mutation in sheep may result in RBC sickling and a SCD phenotype similar to that seen in human patients. The principal hypothesis of this proposal is that introduction of the SCD mutation in sheep cells will produce a similar disease phenotype in the sheep model. The second hypothesis that we will be testing in this proposed project is that the use of serum-free oocyte maturation and embryo culture media will reduce the incidence of sheep large offspring syndrome and thus would improve efficiency of Somatic Cell Nuclear Transfer (SCNT) and health status of the offspring produced by SCNT. As SCNT is the primary method for production of gene-edited livestock (Perisse et al. 2021), especially when homology directed repair mechanism is used, the scientific knowledge generated in this project and potential improvements of SCNT efficiency would not be only beneficial for this project but would have a broad impact on livestock SCNT and gene-editing field and their agricultural applications.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

This is a new project that was initiated 6 months ago. We previously used CRISPR/Cas9 editing technologies to introduce the single nucleotide mutation present in human SCD into the β -globin locus of male sheep fibroblasts. We have transfected female cell line and in a process of isolating SCD colonies for future cloning.

Blood from previously produced SCD lambs and age-matched controls were evaluated by the same diagnostic methods used in humans: hematocrit, blood smears, reticulocyte counts, alkaline and capillary hemoglobin (Hb) electrophoresis, Hb solubility tests, and ektacytometry. Peripheral blood (PB) smears in SCD animals exhibit sickled erythrocytes, acanthocytes, target cells, normoblasts, and polychromasia, while AMC displayed normal PB smears. SCD animals displayed positive SickDex tests at birth and at all time points analyzed thereafter; these tests were consistently negative in AMC. Alkaline and capillary Hb electrophoresis demonstrated the presence of an abnormal Hb with the same migration pattern as the human HbS, and the presence of HbF at birth. HbF waned progressively to disappear by 3 months, being replaced by HbS in SCD lambs and normal adult Hb in AMC. These data indicate that introduction of the human SCD mutation in the sheep β -globin gene results in a similar phenotype at the blood level, thereby potentially producing a similar disease phenotype and progression in the sheep model.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audiences for this project consist of: (1) research scientists involved in the production and use of genetically engineered large animal models for agricultural and biomedical research; (2) animal scientists interested in the use of new technologies for genetic modification of livestock; and (3) researcher and medical professionals interested in developing therapeutic interventions for Sickle Cell Disease.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No changes to the plan of work.

Training and Professional Development:

An abstract summarizing this project results was recently reviewed and published:

Kuczynski C.E., I.V. Perisse, M. Regouski, E. Alipour, C. LaPradd, Y. Liu, M. W. Beaty, D. B. Kim-Shapiro, A. Atala, **I. Polejaeva**, C. D. Porada, M. G. Almeida-Porada*. (2022) Novel sheep model of sickle cell disease reproduces human clinical and laboratory parameters. *Blood* 140 (1) 8220-8220. It will be presented at the American Society of Hematology Conference.

Dissemination:

The results of this project were presented at a national meeting listed above. The data are in preparation for a peer-reviewed publication.

Plan of Work:

We are planning to produce SCD female cell colonies by CRISPR/Cas9 and use them for cloning in the fall of 2023.

Food Insecurity and Health at the Intersection of Disability and Other Socially Disadvantaged Identities in the Intermountain West

Project Director

Guadalupe Marquez-Velarde

Organization

Utah State University

Accession Number

1026659



Food Insecurity and Health at the Intersection of Disability and Other Socially Disadvantaged Identities in the Intermountain West

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Although the negative effects of food insecurity on physical, psychological, and behavioral health are becoming increasingly well-documented, risk factors for food insecurity and its associated negative health effects are understudied in households that include individuals with disabilities, particularly at the intersection with other characteristics of social disadvantage. While some studies have addressed the risk factors of disability for food insecurity among working-age adults or households

with children who have a disability, no studies to date have examined the potentially deleterious effects of food insecurity in this vulnerable population, especially among individuals with other potentially marginalizing identities. In order to research the associations between food insecurity and health from an intersectional perspective, my proposed project addresses the following three objectives:

1. Conduct further studies using the quantitative dataset funded by UTA-01491, a UAES seed grant ending April 30th, 2021.
2. Identify an external funding mechanism to deploy a follow-up survey.
3. Improve the previous survey instrument and collect a second wave of data.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

During the reporting period, I accomplished the following:

1. I published one article with a team of graduate* and undergraduate students** using the UAES-funded data:

Shircliff, Jesse E.*, Jordan Hammon*, Carina Linares**, Teresa Larsen*, and **Guadalupe Marquez-Velarde**. 2022. "Economic Inequality during Covid-19 as a Pathway to Food Insecurity for People who are Disabled and Racialized as Non-White". *Journal of Hunger & Environmental Nutrition* <https://doi.org/10.1080/19320248.2022.2133982>

2. I worked in a second manuscript with faculty and a graduate student from the department of Nutrition, Dietetics and Food Sciences, and a colleague in Sociology. The manuscript is in final editing stages and should be submitted for peer-review in early spring 2023. We are targeting the Disability and Health Journal.

Christy-Voorhees, McKenna*, Heidi J. Wengreen, Mateja R. Savoie-Roskos, **Guadalupe Marquez-Velarde**, and Gabrielle Ciciurkaite. "Disability and Health: The Role of Food Security as a Potential Mediator."

3. I am also working with former master's student Jordan Hammon in editing her master's thesis (which used the UAES-funded dataset). We aim to have a suitable manuscript for publication next year. We are targeting the journal Social Currents.

Hammon, Jordan F., **Guadalupe Marquez-Velarde**, and Gabrielle Ciciurkaite. "Precarious Labor and Access to Healthcare in the Intermountain West."

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

During the reporting period, I analyzed data related to food insecurity and health, collected in 2020 and sponsored by a UAES seed grant. The data is comprised of 2,043 adult respondents living in the Intermountain West region (Utah, Colorado, Idaho, Montana, Wyoming, Nevada, Arizona, and New Mexico).

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

I have struggled finding more collaborators on campus and have had difficulty promoting the broader use of this data resource. However, I have been contacted by a team of researchers in Italy who wish to collaborate in a methodological piece using the data. I will explore this opportunity next year.

Training and Professional Development:

This year, I worked with students and provided training in data analysis and manuscript development. I also worked with one graduate student in developing his team and project management skills.

Dissemination:

During the reporting period, the paper "Economic Inequality during Covid-19 as a Pathway to Food Insecurity for People who are Disabled and Racialized as Non-White" was discussed at a refereed roundtable at the American Sociological Association 2022 meetings in Los Angeles, CA.

Plan of Work:

During the next reporting period, my priority will be to finalize the manuscripts in progress and to start identifying sources of extramural support to fund a second wave of data collection.

Global Farm and Trade Policies, Health, and Implications for Regional Development

Project Director

Sherzod Akhundjanov

Organization

Utah State University

Accession Number

1026559

**Global Farm and Trade Policies, Health, and Implications for Regional Development**

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective 1: Model and examine the effects of recent global farm and trade policies on regional economic development;

Objective 1.1: Develop a theoretical trade model of (continuum of) agricultural goods encompassing Ricardian and/or Heckscher-Ohlin comparative advantage, domestic farm policies, and trade policies in the presence of strategic domestic politics and/or environmental concerns;

Objective 1.2: Empirically implement the model by econometrically estimating the trade flow equations and quantify the effects of farm supports and trade barriers on prices, trade flows, production, consumption, returns to primary and intermediate factors, and welfare;

Objective 1.3: Simulate the model to analyze the effects of recent trade agreements, trade wars, and related policies on regional economic development.

Objective 2: Model and examine the effects of the COVID-19 pandemic on bilateral trade and regional economic development;

Objective 2.1: Develop a theoretical model to analyze the effects of the COVID-19 pandemic on international trade in food and agriculture and regional economic development, taking care to distinguish between the impacts arising from supply-based versus demand-based factors;

Objective 2.2: Study the statistical properties of the pandemic and econometrically estimate its effects on bilateral trade, production, consumption, financial markets and welfare across both industries and countries.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

OBJECTIVE 1.1:

Completed the write up (first draft) of a research project examining an interplay between trade, political economy, and environment. This work is co-authored with Dr. Devadoss (Texas Tech University).

In response to journal reviewers' and conference participants' comments and suggestions, revised the draft of a research project examining the effects of rural-urban water trade on agriculture and regional economic development. This work is co-authored with a former APEC graduate student (Muyang Ge) and Dr. Edwards (North Carolina State University) and Dr. Oladi (APEC).

Complete an expanded analysis of a research project exploring the implications of rural-urban water trade for urbanization and economic activity. This work is co-authored with a former APEC graduate student (Arpita Nehta) and Dr. Oladi (APEC) and Dr. Caplan (APEC).

OBJECTIVE 1.2:

Published in a peer-reviewed journal (in 2022), a research project examining the growth process of U.S. agricultural land size. This work is co-authored with a former APEC graduate student (Tatiana Drugova). The findings of this work will inform our empirical analyses related to this objective.

OBJECTIVE 2.1:

Completed a research project studying the effects of the COVID-19 pandemic on international trade in food and agricultural products. This work, which is co-authored with Dr. Ridley (University of Illinois, Urbana-Champaign) and Dr. Devadoss (Texas Tech University), has recently been accepted for publication in a peer-reviewed journal. This study is directly relevant to this objective.

OBJECTIVE 2.2:

Published in a premier statistics/mathematics journal (in 2022), a research project analyzing the statistical distribution of COVID-19 cases in China. This work, which is co-authored with Dr. Ahundjanov (University of Illinois, Chicago) and Mr. Okhunjanov (Denison University). This study is directly relevant to this objective.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Academia, professional researchers, policy makers

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

None

Training and Professional Development:

In 2022, two graduate students that I was advising as a committee member have successfully defended their dissertation/thesis. In particular, Janette Goodridge, whose committee I served as a member, successfully defended her PhD Economics degree in the Fall of 2022. Janette has recently accepted an Assistant Professor in Practice position at the Department of Economics at Utah State University. Julie Norman, whose committee I served as a member, successfully

defended her MS Economics (Dept of Econ and Fin) degree in the Summer of 2022.

In 2022 one undergraduate student (Hadjer Abir Bensaha, Dept of Econ and Fin) that I was advising as an Honors Undergraduate Research Advisor has also successfully defended her capstone project.

Currently, I am serving in the committees of two graduate students. In particular, as a chair: Haishan Yang (APEC PhD Econ) and Brigitte Mueces (APEC PhD Econ). Students are showing a steady progress in their research work.

Dissemination:

The results of my scholarly work have been disseminated to communities of interest (academia, professional researchers, and policy makers) by means of journal publications and conference presentations. In 2022, I have published or had accepted for publication three articles in peer-reviewed academic journals. Further, my research papers have been presented at six national/international professional conferences, including American Statistical Association (ASA), Agricultural and Applied Economics Association (AAEA), European Association of Environmental and Resource Economists (EAERE), Asian Meeting of the Econometric Society (AMES), Midwest Economics Association (MEA), and International Industrial Organization Conference (IIOC).

Products:

Publications:

Refereed Journal Articles:

Ahundjanov, B. B., Akhundjanov, S., & Okhunjanov, B. B. (2022, March). Power Law in COVID-19 Cases in China. *Journal of the Royal Statistical Society: Series A*, 185(2), 699-719.

Akhundjanov, S., & Drugova, T. (2022, January). On the Growth Process of U.S. Agricultural Land. *Empirical Economics*, 63(3), 1727-1740.

Ridley, W., Akhundjanov, S., & Devadoss, S. (in press). The COVID-19 Pandemic and Trade in Agricultural Products. *To appear in The World Economy*.

Other Products:

Data and Research Material - Collaborating with a former APEC graduate student (Muyang Ge) and Dr. Edwards (North Carolina State University) and Dr. Oladi (APEC), expanded the scope of the previous research project looking at agricultural, environmental, economic, and health implications of rural-urban water trade.

Data and Research Material - Collaborating with a former APEC graduate student (Arpita Nehta) and Dr. Oladi (APEC) and Dr. Caplan (APEC), continued to explore the implications of rural-urban water trade for urbanization and economic activity.

Data and Research Material - Collaborating with Dr. Devadoss (Texas Tech University), theoretically modeled the nexus between political economy, environmental policy, and trade.

Data and Research Material - Collaborating with Dr. Jakus (APEC), continued to study the implications of public lands for quality of life in urban areas.

Data and Research Material - Collaborating with a former graduate student (Arthur Wardle), revised our previous study examining the implications of the Renewable Fuel Standards on the regulated industries' financial portfolio.

Data and Research Material - Collaborating with a former graduate student (Wai Yan Siu), revised our previous study examining the impact of hydraulic fracturing on agricultural productivity.

Data and Research Material - Collaborating with Dr. Smith (University of Nebraska) and Dr. St. Brown (Oregon Municipality), modeled the implication of path dependence in consumer product design on consumer welfare.

Data and Research Material - Collaborating with a team of scientists and graduate students from the University of Utah, studied temporal and spatial dynamics in Hepatitis Delta Virus and its implications for social welfare.

Plan of Work:

1) Pursue completion and/or revision of papers listed for Objective 1.1 and Objective 2.1 in Accomplishments, and seek their publication.

2) Prepare drafts of the new research papers listed for Objective 1.1 and Objective 2.1 in Accomplishments for submission to a refereed journal.

Obesity, Wellbeing, and Longevity: Persistent Inequalities and Pathways to Change in Disadvantaged Populations

Project Director

Eric Reither

Organization

Utah State University

Accession Number

1026558



Obesity, Wellbeing, and Longevity: Persistent Inequalities and Pathways to Change in Disadvantaged Populations

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

The three main objectives of this UAES research project are: (1) to characterize the impact of obesity on wellness and longevity in disadvantaged populations — including racial/ethnic minorities and persons living in rural areas, Utah, and the Intermountain West; (2) to investigate upstream contributors to obesity incidence and prevalence, suboptimal wellbeing, and reduced longevity in these same disadvantaged populations; (3) to identify pathways to reduce the incidence and prevalence of obesity, improve wellbeing, and extend longevity in disadvantaged populations.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

In the second reporting period for this UAES project, my research activities addressed all three project objectives, namely to (1) characterize the impact of obesity on wellness and longevity in disadvantaged populations, (2) investigate upstream contributors to obesity incidence and prevalence, suboptimal wellbeing, and reduced longevity, and (3) identify pathways to reduce the incidence and prevalence of obesity, improve wellbeing, and extend longevity. In a study addressing all three aims, I collaborated with a graduate student (Max Roberts) and USU faculty member (Sojung Lim) to investigate how obesity-related causes of death (e.g., diabetes and heart disease) have contributed to losses in life expectancy among non-Hispanic Black and White residents of the Great Lakes region (i.e., Wisconsin, Michigan, Ohio, Illinois, and Indiana). By combining restricted-use mortality data from the National Center for Health Statistics with population data from the American Community Survey, we created and subsequently decomposed a series of life tables for 12 race-gender-education groups (e.g., Black females with some college) across two time periods (i.e., 2009 and 2016). We found that life expectancy declined for 9 of 12 groups; only college-educated groups experienced small gains in life expectancy, except for college-educated Black males, who lost 0.4 years between 2009 and 2016. Over this period, life expectancy declined by more than a year among White males and females with no college, and Black females and White males with some college. Although drug poisoning was the largest contributor to these losses for most groups, it had relatively little effect among Black females with some college education. For this group, diabetes and heart disease accounted for 0.66 of the 2.22-year loss in life expectancy. Our findings reveal that the opioid and obesity epidemics have occurred simultaneously in the Great Lakes region to arrest and even reverse previous gains in life expectancy. In another project investigating the second and third aims, I worked with Yin Liu (USU) and a group of colleagues at Wisconsin and Stanford to examine how between-person (BP) differences and within-person (WP) changes in sleepiness affect body mass among persons in the Wisconsin Sleep Cohort Study. This NIH-supported study found that men with high levels of sleepiness at baseline were more likely to have elevated body mass than men with low levels of sleepiness. Perhaps more importantly, our study also found that WP increases in sleepiness predicted WP increases in body mass among women. These increases in body mass were especially pronounced among relatively young women in the study. In a third study addressing the second and third UAES project objectives, I worked with a graduate student (Olusola Omisakin) and USU

faculty member (Guadalupe Marquez-Velarde) to examine determinants of Black-White disparities in low birth weight (LBW). This subject is an important contributor to my UAES project because LBW is known to affect future life chances, including obesity, overall wellbeing, and longevity. Our preliminary analyses of data from the 2000-2020 National Health Interview Surveys indicate that mother's levels of education and psychosocial distress were significant predictors of Black-White disparities in LBW. In a fourth project addressing the first and third UAES research objectives, I completed work with colleagues at the University of Colorado-Denver to summarize the literature on the causes of obesity disparities and potential policy solutions. Our manuscript comprehensively characterized the state of knowledge regarding obesity and its health consequences in multiple disadvantaged populations.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The main target audience during this reporting period was scholars and practitioners in epidemiology and the social sciences who are interested in (a) crucial public health issues such as obesity and substance use, and (b) racial/ethnic disparities in health and longevity.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

I do not anticipate any notable changes or problems to my UAES objectives between now and the project end date.

Training and Professional Development:

In this reporting period, my UAES project provided excellent research training and professional development opportunities Olusola Omisakin, a Ph.D. student in Sociology. With ongoing UAES support, Mr. Omisakin is making excellent progress toward degree completion and professional development. As noted, Mr. Omisakin examined determinants of Black-White disparities in low birth weight, which in turn influences future life chances, including obesity, overall wellbeing, and longevity. In addition, Mr. Omisakin received training in sophisticated latent growth modeling techniques, which he is using in preliminary dissertation analyses to assess key determinants of trajectories in body mass among US adolescents.

Dissemination:

In this reporting period, I disseminated UAES-related research by presenting research and publishing manuscripts. First, our manuscript summarizing the literature on obesity disparities was published by Springer in the International Handbook on the Demography of Obesity. Second, our manuscript on changes in life expectancy among Black and White residents was submitted to *BMC Public Health* for consideration. Third, in a project related to both UAES and NIH funding, our research on associations between sleepiness and body mass was accepted for a symposium presentation entitled "Interactions Between Sleep and Biological Markers of Aging" at the Gerontological Society of America.

Plan of Work:

Over the next year, I will use a second no-cost extension from the NIH to continue research on sleep-obesity associations, which are related to my second and third UAES project objectives. In addition, I plan to work with current and former Ph.D. graduate students and colleagues in Sociology to (1) assess upstream contributors to gains in body mass, (2) estimate the effects of obesity on life expectancy, (3) continue ongoing research on "deaths of despair" in the U.S., and (4) examine how COVID-19 and obesity have jointly affected wellbeing in the U.S.

Optimizing dietary fiber consumption for metabolic health

Project Director

Robert Ward

Organization

Utah State University

Accession Number

1022997



Optimizing dietary fiber consumption for metabolic health

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

- 1) Using a database of fiber profiles for 244 foods, determine the fiber profiles for several recommended high fiber diets. These will include diets recommended by the Institute of Medicine to meet recommended fiber intakes.
- 2) Using an in vitro digestion method, determine how the actual fiber levels in the recommended diets compare to estimated levels derived from the database.
- 3) Evaluate the relative fiber composition (i.e. cellulose, hemicellulose, pectin, lignin, β -glucan) of available fiber extracts from fruits and grains.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

In 2022, an MPH student did further in silico work to characterize fiber profiles from common diets consumed in the US. These diets included the DASH diet, the Paleo diet, a typical American diet, the Mediterranean diet, and a Japanese diet.

The fiber profiles from these diets were used to formulate a rodent diet for a USDA funded feeding study.

In addition, in 2022 an undergraduate student implemented an in vitro digestion method. In 2023, this method will be used to determine the fiber profiles of substrates used in the rodent diets.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

The target audience for this project will be food scientists, nutrition scientists, and dietitians. The results will be published in peer-reviewed journals, and presented at international conferences.

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

There were no problems in 2022.

Training and Professional Development:

In 2022, an MPH student conducted a further in silico analysis of common human diets to expand on work previously done, and used the data in his MPH thesis.

In 2022, an undergraduate worked on a new and improved in vitro digestion method to characterize dietary fibers.

Dissemination:

The results from the in silico analysis were included in a graduate students MPH project.

Publications:

Refereed Journal Articles:

Kung, S., Vakula, M., Kim, Y., Derek, E., Bergeson, J., Bressel, E., Lefevre, M., & Ward, R. E. (2022, October 29). No effect of a dairy-based, high flavonoid pre-workout beverage on exercise-induced intestinal injury, permeability, and inflammation in recreational cyclists: A randomized controlled crossover trial. *PLOSOne*, 17(11), 1-20.

Plan of Work:

In 2023, we will characterize the dietary fibers used to prepare rodent diets using the in vitro digestion method.

Closing Out (end date 06/12/2024)

[Black raspberries for suppression of colitis induced by human-to-mouse fecal microbiome transfer from ulcerative colitis patients.](#)

Project Director

Abby Benninghoff

Organization

Utah State University

Accession Number

1019994



Black raspberries for suppression of colitis induced by human-to-mouse fecal microbiome transfer from ulcerative colitis patients

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective 1: Determine impact of repeated fecal microbiome transfer (FMT) from healthy or ulcerative colitis (UC) human donors on colitis symptoms, microbiome composition and biomarkers of inflammation in recipient mice fed either a healthy diet (AIN), a Western type diet (TWD) or the TWD with 10% BRB.

Objective 2: Determine how mice that received FMT from UC or healthy patients respond to acute colitis stress by using the DSS model of chemically-induced colitis in mice fed either a healthy diet (AIN), a Western type diet (TWD) or the TWD with 10% BRB.

Timeline

Recruit human donors and sequence microbiomes - year 1

Perform FMT study (in cohorts) - years 2-3

Analyze recipient mouse microbiomes- year 3

Biomarkers of inflammation (immunohistochemistry, histopathology) - years 3-4

Differential gene expression by Fluidigm - years 3-5

Data analysis - years 3-5

Preparation of manuscripts years 4-5

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

As noted last year, research plans have shifted somewhat to account for earlier delays due to the pandemic and the need to better understand the effects of black raspberries (BRB) on inflammation and colorectal cancer in our pre-clinical model prior to performing a human-to-mouse fecal transfer study. In brief, that work is now concluded. In our recent publication (Rodriguez, et al. 2022) we determined that BRB supplementation markedly altered the composition of the fecal microbiome in mice prior to chemical induction of gut injury; this effect persisted throughout active colitis, recovery from gut injury, and development of colon tumors. However, results of repeated experiments provided equivocal results regarding the potential of BRB to suppress immune response.

Further, as described last year, we performed a mouse-to-mouse study to determine whether dynamic transfer of a gut microbiome from mice with severe colitis and a high tumor burden would worsen disease symptoms in recipient mice. Of note, those recipients were fed either a healthy or western type diet. Interestingly, and in agreement with some of our prior work in an obesity model, fecal microbiota transfer from mice with severe disease did not worsen symptoms in recipient mice fed a healthy diet. Rather, the basal diet appeared to be the major driver of the fecal microbiome composition and colitis symptoms in recipient mice. This work will be submitted for publication in early 2023.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

International medical community, scientific community

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

Given the new information from these studies outlined above studies, we feel that we can now get back on track with the planned human-to-mouse FMT study.

Training and Professional Development:

Training of undergraduate and graduate personnel in laboratory methods, including nucleic acid extraction, PCR, RNA sequencing, data analysis. Training of undergraduate personnel in literature searching, assessment of scientific papers, and scientific writing. Training of all personnel in laboratory animal husbandry, necropsy, and pre-clinical animal study design. Four undergraduate student researchers: Abi Weaver, Marcus Hayden, Jeremy Case, Sam Rice; Graduate students: Daphne Rodriguez, Mohammed Almatani, Eliza Owens

Dissemination:

Publications:

Rodriguez, D.M.; Hintze, K.J.; Rompato, G.; Wettter, A.J.V.; Ward, R.E.; Phatak, S.; Neal, C.; Armbrust, T.; Stewart, E.C.; Thomas, A.J., et al. Dietary supplementation with black raspberries altered the gut microbiome composition in a mouse model of colitis-associated colorectal cancer, although with differing effects for a healthy versus a Western basal diet. *Nutrients* **2022**, *14*, doi:10.3390/nu14245270.

International Conference Presentation:

Daphne Rodriguez, Abby Benninghoff, Korri Hintze, Giovanni Rompato, Eliza Stewart, Fecal Microbiota Transfer to Determine the Contribution of the Gut Microbiome in a Mouse Model of Western Diet-Enhanced Colorectal Cancer, Current Developments

Other Products

Data and Research Materiale Dataset for fecal microbiome profiling studies obtained in a pre-clinical experiment to determine health benefits of black raspberry supplementation for suppression of colitis and inflammation associated colorectal cancer. This work was partially supported through this project. These data are in support of a new publication Rodriguez, D.M.; Hintze, K.J.; Rompato, G.; Wettete, A.J.V.; Ward, R.E.; Phatak, S.; Neal, C.; Armbrust, T.; Stewart, E.C.; Thomas, A.J., et al. Dietary supplementation with black raspberries altered the gut microbiome composition in a mouse model of colitis-associated colorectal cancer, although with differing effects for a healthy versus a Western basal diet. *Nutrients* **2022**, *14*, doi:10.3390/nu14245270.

All raw data supporting this work are freely available via the Utah State University Digital Commons Data Repository at <https://doi.org/10.26078/ats5-4m77>, including:

1. Benninghoff_Experiment_A_mapping_file.csv provides the sample identification details including the time point, basal diet, black raspberry (BRB) supplementation for each sample ID.
2. Benninghoff_Experiment_A_OTU_table.csv provides the 16S rRNA sequence count data for all samples for each operational taxonomic unit identified.
3. Benninghoff_Experiment_A_taxonomy.csv provides the mapping of operational taxonomic units to bacteria taxonomy.
4. Benninghoff_Experiment_B_mapping_file.csv provides the sample identification details including the time point, basal diet, black raspberry (BRB) supplementation for each sample ID.
5. Benninghoff_Experiment_A_ASV_table.csv provides the 16S rRNA sequence count data for all samples for each amplicon sequence variant identified.
6. Benninghoff_Experiment_A_taxonomy.csv provides the mapping of amplicon sequence variants to bacteria taxonomy.
7. Readme.txt

Plan of Work:

With data in hand, we are reasonably confident to proceed with the human-to-mouse fecal transfer study using human fecal samples from healthy or patients with ulcerative colitis into mice fed either a control diet or a diet with BRB. However, our hypothesis will likely need refining. While we can predict that BRB will alter the microbiome of mice that receive fecal microbiota transfer (FMT) from human donors, our pre-clinical study results do not strongly support a hypothesis that BRB supplementation would suppress inflammation in these mice. Further, as FMT from mice with severe disease did not worsen disease in recipient mice, we may not expect that FMT from ulcerative colitis patients will worsen symptoms in recipients. Although our expected outcomes may have shifted with new data from our pre-clinical work, this planned human-to-mouse FMT study will yield important new data that provide new knowledge on the direct contribution of gut bacteria to colitis and the potential for dietary supplementation to change the bacteria composition and/or suppress gut inflammation.

Public Nutrition and Health Education

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7001913



Chronic Disease Prevention

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Chronic diseases are the leading causes of death and health care costs in Utah. There is an ongoing need to develop Extension programs to promote sustainable and healthy lifestyles by applying integrated approaches to reducing chronic disease. In Cache County Utah. J. Dyckman and A. Litchford expanded the focus on a diabetes education program.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The Diabetes Cook Along Classes were piloted in Box Elder and Cache County. The classes were expanded in 2022 to two other counties. The program aimed to reduce individuals' risk for chronic diseases and to help them manage their chronic diseases. The 4-week in-person diabetes education program combined lecture-based learning and hands-on cooking experience. Each class included information to help individuals with diabetes or pre-diabetes better manage their disease symptoms. Participants prepared a diabetes-appropriate meal during the class, participated in discussions, and set goals to make lifestyle changes.

Briefly describe how your target audience benefited from your project's activities.

A total of 30 participants attended the program. Evaluation results showed 95% of participants in the diabetes cooking classes said they were satisfied or very satisfied with the information provided in classes. Results indicated all participants experienced an increase in knowledge of the concepts covered in the curricula. Most participants also reported positive changes to their lifestyle behaviors (e.g., checking blood sugar levels daily, exercising daily, taking medication as prescribed, and limiting carbohydrate intake daily).

Briefly describe how the broader public benefited from your project's activities.

J. Dyckman noted the evaluation results demonstrated program value, stating, "this program was able to help individuals with diabetes to implement small changes to help them increase in their confidence and ability to manage their diabetes successfully."



Diabetes Prevention and Management

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

In Utah, over 180,000 people have been diagnosed with diabetes ([Health Indicator Report of Diabetes Prevalence, 2021](#); [QuickFacts Utah, n.d.](#)), and an estimated 38% of adults have prediabetes ([National Diabetes Statistics Report Website, 2022](#)). Diabetes can result in serious health complications ([Papatheodorou et al., 2016](#)). In 2020, only 12,859 people with diabetes participated in a Diabetes Self-Management Education and Support (DSMES) program ([DSMES State Data - Annual Status Report, 2020](#)). Of the estimated 652,000 adults with prediabetes, approximately 1,500 per year complete the National Diabetes Prevention Program (National DPP) ([DPRP State-Level Evaluation Report, 2019](#)). In addition to other barriers, the Centers for Disease Control and Prevention has identified low awareness of program availability as a gap to participation. Therefore, one way to reduce the disease burden in our population is to increase awareness of program availability. Led by C. Jenkins, USU Extension sought to reduce the burden of preventable diabetes among adults in Utah via a "Food as Medicine" webinar series.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The "Food as Medicine" webinars aimed to increase awareness and enrollment in public diabetes programs while providing informative content about beneficial lifestyle changes. Key partners included the Utah Department of Health and Human Services, Utah State University (USU) Extension, University of Utah, the Steering Committee for the Prevention of Diabetes, the Utah Diabetes Coalition, Get Healthy Utah, and several Utah local health departments. The public diabetes programs highlighted the following initiatives; (a) National Diabetes Prevention Program, (b) Diabetes Self-Management Education and Support (DSMES) Toolkit, and (c) Walk with Ease (WWE) program.

Webinars were conducted through Zoom in 2021 and 2022; three were delivered in English and one in Spanish. The webinars were promoted through social media to target individuals comfortable with technology. Each webinar provided nutrition and health information, a demonstration of a healthy recipe, and information about public diabetes programs in Utah. The webinar series targeted adult individuals in the state of Utah diagnosed with diabetes or at risk of developing diabetes. These individuals tend to be older, have lower incomes, and come from minority race/ethnicity categories.

Based on the evaluation data (n = 39), the Food as Medicine webinar series had effective program coverage; 13% of participants had a diagnosis of diabetes, and 21% were diagnosed with prediabetes. Also, 21% of participants were below the poverty level in 2021, and 44% were 65+ years old. However, participation did not include all of the gender and minority populations of interest.

Briefly describe how your target audience benefited from your project's activities.

The evaluation questionnaire used a combination of multiple choice, open-ended, and Likert-type questions to gather data on participants' perceived value and knowledge gained from the program. Descriptive statistics were conducted on quantitative data and thematic analysis was conducted on qualitative data. Results indicated that participants of the webinars appreciated the information provided about the various public diabetes programs. Approximately 28% of participants were extremely likely or somewhat likely to enroll in the National DPP; 44% were extremely likely or somewhat likely to enroll in DSM ES, and 50% stated that they were extremely likely or somewhat likely to enroll in WWE.

Most respondents agreed with the statement that the webinars increased their awareness of these programs. These results show that one major objective of these webinars was accomplished by increasing public knowledge about evidence-based diabetes programming. Respondents also reported a positive experience with the virtual structure for these classes (i.e., Zoom), and commented positively on session flow. Over half of the number of respondents indicated they would be extremely likely or somewhat likely to recommend the webinar series to others. Qualitative comments were generally positive with respect to the content of the webinars, the quality of the presenters, recipe demonstrations, and the convenience of attending online. Lastly, most comments regarding something learned were focused on food choices i.e., new recipes, meal planning, eating habits, and specific foods.

Briefly describe how the broader public benefited from your project's activities.

Overall, the Food as Medicine webinar series provided valuable health information to 124 live participants and 123 viewers of recorded sessions. The total reach of this program was 247 views, an encouraging number despite the possibility that some of these views could be from the same individual. Based on the evaluation, participants were more likely to enroll in the featured programs given their increased awareness of these programs. Notably, participants reported the cooking demonstrations to be the most enjoyable aspect of the webinar, which may lead to the use of new recipes, cooking techniques, or healthy ingredients at home. Survey respondents were very likely to refer this webinar series to others, illustrating that this type of community education class is an acceptable format to educate the general public.

The evaluation results will be used to inform future health-based webinar interventions in the state of Utah. Mainly, the use of virtual platforms, the inclusion of cooking demonstrations, and publicly shared recordings appear to be productive engagement tools. However, these webinars did not engage underrepresented gender and ethnic minority populations so more will be done to facilitate engagement with these groups. Examples may include working with stakeholders from minority coalitions and communities to be part of our planning and advisory teams, increasing outreach through existing partnerships with organizations serving these communities, and adding new sessions similar to the Spanish language session for other populations.



Statewide Create Better Health Programming

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Food insecure, low-income adults and youth are more likely to have poor diet quality and physical activity behaviors contributing to an increased risk of chronic health conditions including, but not limited to obesity, Type II diabetes, heart disease, and certain cancers. Improving the dietary and physical activity behaviors of individuals through improved knowledge, skills, and access may improve individuals' health trajectories, outcomes, and overall quality of life. Utahns experiences hunger, poverty, unemployment, and many other hardships that contribute to an increased risk of obesity and chronic diseases. Over 14% of Utah households are food insecure and 12.7% of Utahns are living in poverty. Utah has a fairly low unemployment rate of 3.8%, however, many Utah families are considered working poor as a result of working part-time or full-time jobs with low wages. Eighty-three percent of low-income families have a family member who works, however, only thirty-five percent of children in poor families have at least one full-time working parent.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

While food insecurity remains a public health concern among adults and youth living in poverty, this population is also experiencing overweight and obesity at higher rates than their middle and high-income counterparts. Improving dietary habits and physical activity behaviors of low-income populations may help prevent or reduce health conditions associated with poor diet and sedentary lifestyles. Create Better Health Utah (CBH), led by H. LeBlanc, offers group nutrition education

classes to adults and youth, implements policy, systems, and environmental strategies to improve healthy food access for the target audience, and uses social marketing campaigns and social media platforms that aim to improve diet and physical activity of those reached.

Briefly describe how your target audience benefited from your project's activities.

Short-term evaluation results of direct CBH educational activities indicated that after participating in a virtual or one-time class, adult participants (n = 307), 45% intended to stretch their food dollars to last the month more often, 51% intended to choose a variety of foods based on MyPlate more often, 47% intended to be physically active for at least 30 minutes, 5 days a week more often, and 33% intended to adjust their meals to use foods on hand more often.

For medium-term outcomes, 57% reported an increase in fruit intake since the start of the CBH series, 50% reported an increase in vegetable intake since the start of the CBH series, 52% reported adjusting meals to use foods on hand more often, 62% reported an increase in the number of days they were physically active for at least 30 minutes, 61% reported using MyPlate recommendations to make food choices more often, 48% reported stretching their food dollars to last the month more, and 49% reported using a grocery list to shop more often. In addition, results of the non-parametric Wilcoxon signed-rank test indicated there was a statistically significant increase in participants' vegetable intake after they completed the program (W = 3.42, p < 0.001).

With respect to long-term impacts (i.e., 6 months after completion), 50% reported using MyPlate recommendations to make food choices more often, 25% reported having enough food to last the month more often, 50% reported eating more vegetables, 29% reported eating more fruits 50% reported being more physically active, 28% reported adjusting meals to use foods on hand more often, 56% reported using the nutrition facts label more often, 44% reported choosing foods with less added sugar more often, and 44% reported choosing foods with less sodium.

CBH also conducts nutrition programs for youth. Medium-term evaluation results indicated youth in 1st and 2nd grade (**n = 503**) improved their recognition of healthy snacks (37%), fruits (23%), and dairy foods (22%). Youth also recognized proper hand washing (33%) and physically active behaviors (17%). Youth in **3rd - 6th grade** (n = 722) reported eating more vegetables (23%), fruits (24%), and healthy snacks (26%). Youth also reported an increase in physical activities (27%) and hand washing before eating (20%).

Briefly describe how the broader public benefited from your project's activities.

Create Better Health aims to to help people cook healthy meals on a budget, buy and prepare whole foods, understand food labels, practice safety in the kitchen, and much more. With the increase in disease and obesity in the United States, there is an obvious need for more education to promote positive lifestyle changes. Evaluation results show Create Better Health is increasing the knowledge, skill set, and overall well-being of adults and youth across the state.

Critical Issue

Youth Development

A framework for secondary schools agriscience education programs that emphasizes the STEM content in agriculture

Project Director
Tyson Sorensen
Organization
Utah State University
Accession Number
1014434



A framework for secondary schools agriscience education programs that emphasizes the STEM content in agriculture

Final Result

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Goals/Objectives:

Objective which I will be working on:

2. Identify teaching methods, resources (facilities, equipment, materials, etc), and techniques currently utilized by exemplary teachers.

Other Project Objectives:

1. Facilitate the adoption of an agriscience curriculum framework that is grounded in the concepts and approach of the Next Generation Science Standards. Comments: a) Identify practices and cross-cutting concepts from the Next Generation Science Standards to be included in a secondary school agriscience program. b) Disseminate the curriculum framework to secondary agriculture teachers and teacher educators.

3. Develop an innovation configuration for implementing an agriscience program.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Accomplishments:

I focus on Objective 2 for this project: Identify teaching methods, resources (facilities, equipment, materials, etc.), and techniques currently utilized by exemplary teachers. I have collaborated with a colleague at Michigan State in developing a study to identify exemplary STEM teaching within SBAE. Through this collaboration, we have designed a qualitative study, gotten an IRB approval, conducted interviews, and have begun analyzing the data. The data is from teachers in Utah and also from Michigan.

I have worked with a former PhD student and colleague in disseminating her dissertation research related to teaching methods, resources, and techniques used by teachers specific to SocioScientific Issues (SSI) in agriculture, food, and natural resources areas. This research study has been disseminated to a national audience of teacher educators and researchers as a paper presentation with plans for dissemination through peer-reviewed journals.

Briefly describe how your target audience benefited from your project's activities.

Target Audience:

Agricultural Education Instructors (secondary level)

Dissemination of information from this project has resulted in a change in knowledge for our target audience.

Briefly describe how the broader public benefited from your project's activities.

Nothing to report.

Describe and explain any major changes or problems encountered in approach. Additionally, note opportunities for training and professional development provided, how results have been disseminated to communities of interest, and any new details regarding what the project or program plans to do during the next reporting period to accomplish the goals.

Changes/Problems:

No major changes with the project. Some problems I have encountered in working towards accomplishing objective 2 is reliance on USBE to provide the paperwork, support, and guidance for accomplishing the 3-dimensional learning training project. Additionally, the data collection efforts have been much slower than expected with regard to the qualitative research project because interviews took much longer to schedule and conduct than planned and the data analysis was much slower than expected due to graduate student schedule. While the pace has slowed, we are still making positive progress on this project.

Training and Professional Development:

This project has provided me the opportunity to share about STEM, SSI, problem-based learning, and critical thinking this year to a broader audience. I was able to share with a network of STEM educators in Italy important concepts of SSI integration within the classroom. This training happened in December 2022 in a virtual setting. Additionally, this work will continue as students teachers that I have trained will teach SSIs to these Italian teachers and students through the context of the UN 17 sustainable goals. That will happen this spring. Then in March, I will do a face to face training to STEM teachers and teacher educators in Italy regarding these teaching methods. We still have plans to work with agriculture teachers in Utah related to 3-dimensional learning. That project stalled after USBE delayed funding because of personnel issues.

Dissemination:

I helped to disseminate research related to SSI to a national audience through a paper presentation (See citation below). SSI is an important aspect of exemplary STEM teaching, so this research has much potential impact.

Burrows, M. S., Sorensen, T. J., & Ware, S. (2022, May). SBAE teachers' perceptions, needs, and barriers to teaching socioscientific issues. [Paper presentation]. American Association for Agricultural Education Research Conference, Oklahoma City, OK, USA.

Products:

Presentations:

Wood, M. (Presenter & Author), Sorensen, T. (Author Only), Burrows, M. (Author Only), American Association for Agricultural Education Research Conference, "Positionality of teachers regarding IDE professional development in SBAE," AAAE, Oklahoma City, OK. (May 19, 2022)

Wood, M. (Presenter & Author), Sorensen, T. (Author Only), Burrows, M. (Author Only), American Association for Agricultural Education Research Conference, "SBAE attitudes regarding the utilization and implementation of culturally relevant education practices," AAAE, Oklahoma City, OK. (May 19, 2022)

Wood, M. (Presenter & Author), Sorensen, T. (Author Only), Burrows, M. (Author Only), American Association for Agricultural Education Research Conference, "Attitudes and professional development needs of school-based agricultural education teachers related to inclusion, diversity, and equity," AAAE, Oklahoma City, OK. (May 18, 2022)

Clawson, K. (Presenter & Author), Sorensen, T. (Author Only), American Association for Agricultural Education Research Conference, "Changes in teacher identity and sense of belonging among first-year SBAE teachers in Utah," AAAE, Oklahoma City, OK. (May 18, 2022)

Plan of Work:

I plan to work towards dissemination of research related to SSI this coming year. I plan to get one journal article published (the one presented at the national conference) and another one in the pipeline for publication. I will continue to train teachers about SSI and connection to the UN's sustainable goals. Additionally, I will continue with the exemplary STEM teaching project by finalizing the data analysis and begin dissemination of those findings in this upcoming year. Finally, I plan to continue to conduct training and professional development with teachers to increase skills and knowledge of STEM teaching, including 3-dimensional learning, and SSI integration within agricultural education.

Utah 4-H: Positive Youth Development

Project Director

Lendel Narine

Organization

Utah State University

Accession Number

7001689



Adventure-Oriented Confidence Curriculum for Youth

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Today's youth are consistently exposed to various forms of media that influence them towards the use of substances, having sex at earlier ages, and having poorer body image (de Vries, et al., 2019; Villani, 2001). Additionally, they are likely to experience different forms of adversity in their lives, including a generalized trend of spending more time inside than ever before (Cherlin, 2005; Larsen et al., 2018). These overall conditions and experiences may negatively impact the foundation on which young people build confidence, self-esteem, and resilience. Confidence is an evidence-based component of resilience and youth who have increased confidence may be better equipped to withstand adversity (Merenda, 2020). Therefore, there is a need for youth programs focused on building the confidence of youth.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Led by C. Hansen and team, Utah State University (USU) Extension created a six-session curriculum called *Building Confidence* that seeks to increase confidence in youth. The lessons contain instruction and hands-on learning activities that focus on at least one of the following six areas of confidence (Kay & Shipman, 2014); self-confidence, self-efficacy, connection, contribution, leadership, and teamwork. The Building Confidence curriculum was designed to be taught in six (6) one-hour sessions, and is intended to be used by any adult that works with youth.

The Bear Lake Adventure Camp piloted the Building Confidence curriculum during a three-day overnight camp. Each of the six lessons was presented as intended by a member of the USU Extension team. In addition to participating in the Building Confidence lessons, youth participants also attended adventure-based activities where they learned to overcome challenges. For example, one activity was a ropes course at Bridgerland Adventure Park, while a second was paddle boarding and kayaking on Bear Lake. Participants in this program were males and females ages 12-18 from rural and urban areas of Utah. Twenty-two (22) youth from 11 of Utah's counties participated in the Confidence Building program. They were recruited from existing 4-H programs.

Briefly describe how your target audience benefited from your project's activities.

Youth participants in the camp completed an anonymous post-camp survey which assessed their satisfaction with the camp, perceived skills, and knowledge gain. Overall, results from the survey indicated that 80% of youth enjoyed the camp, and 90% would recommend the camp to their peers. Participants also reported skill acquisition in at least one of the curriculum's focus areas (e.g., self-confidence, self-efficacy). Specifically, 80% of the participants "strongly agreed" or "somewhat agreed" that attending the camp (including workshops and high adventure activities) helped them develop one of the six core confidence characteristics. In addition, 75% of the participants "strongly agreed" or "somewhat agreed" that the lessons helped them develop at least one of the six core confidence characteristics. Even though the program was only piloted, results showed 75% of participants were confident in their abilities to engage in peer mentoring after taking part in the camp. Finally, evaluation findings indicated that female youth participants reported higher increases in skills and knowledge gained compared to male participants.

Briefly describe how the broader public benefited from your project's activities.

Evaluation data were used to guide lesson and activity revisions, as well as to inform best practices for future confidence-building training programs. Data informed the following best practices; (a) limit instruction/lecture time throughout the workshop and incorporate more on the hands-on learning activities; (b) for clarity of instruction, ensure that an adult is present when participants are divided into smaller groups; (c) incorporate music, skits, competitions, and snacks throughout the workshop where possible, and; (d) provide ample time for youth to individually reflect and write in their journals. The revised *Building Confidence* curriculum has since been disseminated to several entities, including the Utah Women in Leadership Project, Utah 4-H Discover Clubs, and Be Epic youth e-cigarette prevention program. There are plans to adapt it to a younger audience and pilot in an after-school setting.



Community Gardens for Youth

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Gardening provides many benefits for youth, such as facilitating physical activity, promoting healthier eating habits, building confidence, relieving stress, helping to develop analytical abilities, and improving focus and memory (Flavin, 2016). The Wayne County 4-H program operated a community garden in the past with limited success. Encouraging youth in farming and agriculture projects has been identified as a priority by county commissioners in Wayne County (Narine, 2021).

Wayne County is a rural county located in central eastern Utah. The county seat, Loa, is approximately 46 miles from Richfield, which is the nearest city with a big box or chain store and where many residents of Wayne County shop. Wayne County is geographically isolated and has a population of 2,711 spread out over a large area of 2,466 square miles. The poverty rate is 11.2% according to the Census Bureau (2021). The USDA has designated Wayne County as a food desert with limited access to grocery stores and other resources.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Led by M. Dabb of USU Extension, the revived Wayne County community garden is an approximately 72 by 40-foot space located on the grounds of the Wayne County courthouse. It has three raised beds, two in-ground perennial beds, a cold-frame hoop house, a compost area, and a hen house for a local 4-H poultry project. Seeds and plants were donated by local businesses and residents. A 4-H summer intern of USU Extension initially built raised beds, in-ground beds, covered the hoop-house, and oversaw planting. Following, grant funds were used to provide Master Gardener Volunteer Training to a volunteer 4-H club leader to lead the garden project. The volunteer started a 4-H Cloverbud (5-8-year-old youth) garden club. The garden club met once a week, and youth and families who participated in the garden kept the produce harvested in the garden. The target audience for the community garden program was youth living in Wayne County and their families. On average, five (5) adults and 15 youth worked in the garden weekly. The youth who participated were primarily 5-8 years old.

Briefly describe how your target audience benefited from your project's activities.

Youth in the 4-H garden club were able to grow radishes in the Wayne County community garden. Youth shared their learning experiences with facilitators, many were excited to nurture the plants and looked forward to taking the harvested radishes home to eat. Many youth were interested in learning more about the produce and were proud of their efforts. Some invited their families to the garden to show off what they did in the garden. Youth were also eager to learn more about sprouting seeds and root systems. Youth experiences in the community garden led to increased interest in local agriculture and motivation to learn more about agricultural sciences.

In total, volunteers and youth provided 291 volunteer hours in the garden. Youth learned basic plant science, including what plants and seeds need to grow and thrive, useful insects, and the role of pollinators. Math skills were also incorporated into teaching since students learned about plant spacing and making the most of out a limited garden space. Students are also learned life skills such as delayed gratification by waiting for seeds to sprout, and creative problem solving and resilience when a project was not successful the first time.

Parents of the youth who participated in the Wayne County community garden also shared their experiences in a short evaluation survey after their children completed the summer garden season. When asked, all parents stated they plan to continue working in the community garden. One parent stated "It was so fun to see the kids' excitement when things would start to grow and when they could eat the food they had harvested." As part of the experience, each child was able to take a pumpkin home for Halloween. Overall, parents indicated their children had increased knowledge of the sources of fruits and vegetables, and had an increased understanding of the importance of eating healthy food. Parents also believed their youth ate more fruits and vegetables because of the community garden, and were willing to try new foods.

Briefly describe how the broader public benefited from your project's activities.

Evaluation results indicated youth and adults of the Wayne County Community garden had positive experiences during their participation in the community gardens. Positive outcomes include increased sense of community belonging, knowledge of local agriculture, consumption of fruits and vegetables, and willingness to try new foods. The next step for the community garden is to create a partnership with the USU Create Better Health program and the Wayne County Food Pantry to develop a system to donate produce from the garden to the local food pantry. The Wayne County community garden represents a significant step towards community partnerships, youth agricultural literacy, and new localized food systems.



As more people move to urban centers in search of job opportunities, rural communities struggle to retain their workforce (Lund et al., 2019; Rogers, 2020). In the first decade of the 21st century, Winkler et al. (2013) estimated the average age-specific net migration per 100 individuals for 17 of Utah's rural counties to be -5.8% for ages 15-19 and -38.6% for ages 20-24. There is an opportunity for rural communities to retain future workforce talent by encouraging youth involvement in remote work education through Utah State University (USU) Extension's Rural Online Initiative (ROI), an economic development program (Hill et al., 2020; Reese, 2018). If youth pursue remote work as a career choice, they have the option to remain or return to their communities and still benefit from well-paying jobs. To address youth migration concerns, A. Schmutz of Utah 4-H teamed up with the ROI program to create the virtual *4-H Remote Skills Camp: For College and Career Readiness*.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

The purpose of the *4-H Remote Skills Camp: For College and Career Readiness* is to equip youth with specialized skills and tools to help them thrive in tomorrow's economy, while also introducing them to best practices of remote work. In an attempt to provide relevant educational programs in Utah, USU Extension conducted a statewide needs assessment (Narine, 2019). This assessment underlined the ongoing deficiency of job opportunities in Utah's rural areas, which has been associated with an increased trend of rural-urban migration and high unemployment rates (Harris & Perlich, 2019; Kumar, 2018; Parker et al., 2018). Narine (2019) identified the top three priority needs for rural Utah counties as: (1) well-paying jobs, (2) quality public schools, and (3) steady jobs. Combining learning modules, interactive workshops, and guest lectures from remote working professionals, the *4-H Remote Skills Camp* was designed to address the needs of well-paying and steady jobs in rural Utah by helping rural youth acquire knowledge and skills in four areas: (a) using remote work tools (i.e., video conferencing platforms, team messaging apps); (b) developing a resume and portfolio; (c) gaining an understanding of effective teamwork and collaboration; and (d) building their problem solving and critical thinking skills.

The 4-H Remote Skills Camp was designed for rural high-school youth aged 15-18 years old with the intent of exposing them to the concept of remote work and increasing their knowledge and skills as future remote workers. The course is a blended, one-month program that combines online work with interactive core content, activities, and quizzes. Participants work at their own pace to complete nine modules and are required to attend eight online workshops with their program coordinators. To earn a certificate, participants must complete all assignments and quizzes, earn a minimum score of 80%, and attend all workshops. The course was facilitated over two separate month-long cohorts with 44 total participants ($N=44$) from 14 states.

Briefly describe how your target audience benefited from your project's activities.

Through observations, facilitators noted positive reactions toward peer interactions through Zoom breakout rooms, group discussions, and Slack channel messaging. This was also observed during group projects, suggesting the peer-to-peer interaction components were highlights of the camp. Facilitators also noted high levels of youth engagement during guest lectures where professional remote workers shared experiences, highlighted careers, and discussed best practices. Observed youth interactions indicated an interest in the application of technology and the process of career development. An exit interview provided participants an opportunity to apply their knowledge of remote work skills coupled with college and career readiness skills. The interview activities included preparing a meeting agenda, creating a meeting/interview invite, and conducting a remote interview where they showcased future plans and shared feedback on their experience with the camp.

Facilitating the 4-H Remote Skills Camp presented a unique set of challenges that we were able to address between the two cohorts. The facilitators' scheduled office hours were underutilized by participants in the first cohort and were changed to an appointment system during the second cohort. Youth preferred direct messaging in Slack instead of live, virtual face-to-face office hours. Maintaining a policy of communication during business hours (9am-5pm) in personal time zones enforced the concepts being taught in the modules.

Briefly describe how the broader public benefited from your project's activities.

The *4-H Remote Skills Camp: For College and Career Readiness* was piloted to determine whether the learning experience was effective in encouraging the development of skills relevant to remote work. Guest speakers and demonstrations led to a high level of participant interest and should be a future component of this online course. Based on what we learned from this pilot, we recommend including interactive activities in the course coupled with the use of social media platforms for peer engagement. Participants also had positive reactions to group discussions about remote work careers and insights into remote work best practices. While this pilot course relied on observational data, creating an evaluation plan and assessing short-term outcomes such as participants' attitudes and aspirations toward remote work opportunities could

enable program improvement. Additionally, based on a recent target audience survey, we recommend implementing a more simplified camp format that would reduce the overall time commitment and make the course more appealing to the target audience of rural high-school youth.



The Impact of Utah 4-H

In 2-3 sentences, briefly describe the issue or problem that your project addresses.

Youth wellbeing is consistently ranked as a high-priority issue by educational and community organizations (Brown & Moore, 2009). On a discussion of the Global Youth Wellbeing Index, Sharma (2017) found only 11% of youth across the globe experienced high levels of wellbeing. In addition, Sharma noted too few young people received the support they need to be successful in life. An emerging area within the broad issue of youth wellbeing is mental health.

The U.S. Surgeon General categorizes *youth mental health* as a major priority area, stating “one in three high school students and half of female students reported persistent feelings of sadness or hopelessness, an overall increase of 40% from 2009” (U.S. Surgeon General’s Advisory, 2021, p. 3). In Utah, youth mental health was identified as an urgent issue in several county-level needs assessments (e.g., Hawkins & Narine, 2022), and a statewide assessment (Narine et al., 2021). Through Utah 4-H, USU Extension is actively engaged in youth development programming to improve the overall wellbeing of Utah’s youth.

Briefly describe in non-technical terms how your major activities helped you achieve, or make significant progress toward, the goals and objectives described in your non-technical summary.

Serving over six million youth, 4-H is the largest youth development program in the U.S. (Flores-Lagunes & Timko, 2014). The mission of 4-H is to “empower youth to reach their full potential through working and learning in partnership with caring adults” (Flores-Lagunes & Timko, 2014, p. 6). Utah 4-H conducts direct programming to youth throughout the state using a “learn by doing” approach. With program coordinators and adult volunteers in every county, youth are provided with a wide range of out-of-school programming opportunities geared toward positive youth development.

4-H Utah program areas include agriculture, environmental, and animal sciences, civic engagement and leadership, family and consumer sciences, healthy living, and science, technology, engineering, and math. Utah 4-H seeks to set youth on thriving trajectories based on their interests. The role of 4-H professionals is to help youth find their interests, contribute to their community and greater society, build their knowledge and skill capacity, and expand their social networks. Environments centered around youth interests, program quality principles, and developmental relationships create a thriving trajectory toward developmental outcomes. This process is summarized as the “6Cs” of Positive Youth Development (Lerner & Lerner, 2012): *Competence, Confidence, Connection, Character, Caring, and Contribution*.

Utah 4-H serves youth between the ages of 5 to 18. Following the zone of proximal development (Vygotsky, 1978), 4-H programs are designed specifically for youth based on their age range and members are categorized into the following groups; Cloverbud (Ages 5 – 7), Junior (Ages 8 – 10), Intermediate (Ages 11 – 13), and Senior (Ages 14 – 18). The distinction between member ages ensures learning occurs by accounting for the developmental phases of youth. By considering program content and context, Utah 4-H is geared towards improving the wellbeing of young people by creating environments where youth can thrive.

Briefly describe how your target audience benefited from your project's activities.

Led by L. Narine and K. Romney, an impact evaluation of Utah 4-H was conducted in 2022. The target population was 4-H youth members, and the sample size was 442 youth ($n = 442$). The sample consisted of youth from grades 5 to 12, and the mean age of participants was 13 years old. All Utah counties were represented except for Emery, Grand, and San Juan counties. An online questionnaire was used to gather outcome data from youth, and 4-H program coordinators throughout the state assisted in administering the survey. Descriptive statistics and logistic regression were used to analyze the data.

Results showed the majority of youth who attended 4-H learned about responsibility, teamwork, leadership, communication skills, problem-solving, goal setting, concern for others, and healthy lifestyle choices. Descriptive results showed most 4-H youth agreed or strongly agreed they learned about making responsible choices, being responsible for their actions, working in a team, maintaining a strong work ethic, helping their community, the importance of mental and physical health, and career options.

A logistic regression was used to assess the long-term impact of Utah 4-H. Youth were categorized into two mutually exclusive groups based on their level of engagement in Utah 4-H; (a) *Lower engagement*= > 1 year of involvement in 4-H *and* > 3 hours a week spent on 4-H activities (*n* = 305), and (b) *Higher engagement*= ≤ 1 year of involvement in 4-H *and* ≤ 3 hours a week spent on 4-H activities (*n* = 117). With age held constant, statistically significant results (*p* < 0.05) of the logistic regression models showed youth with *higher engagement* in Utah 4-H were about 3 times more likely to learn about responsibility, 98% more likely to learn about problem-solving, almost 2 times more likely to learn about goal-setting, 98% more likely to learn about concern for others, and 96% more likely to learn about being responsible for their actions. Compared to those with lower engagement, youth with higher engagement in Utah 4-H experienced a 25% increase in their concern for others, a 22% increase in their goal-setting skills, and a 16% increase in their problem-solving skills.

The long-term impact of Utah 4-H can be summarized by the 6Cs of Positive Youth Development. Results from a series of logistic regression models showed higher engagement in Utah 4-H led to a statistically significant increase in the odds of *all* indicators of positive youth development. With age held constant, results showed youth with higher engagement in Utah 4-H were 70% more likely to demonstrate higher *Competence*, 89% more likely to demonstrate higher *Character*, 80% more likely to demonstrate higher *Connection*, 97% more likely to demonstrate higher *Caring*, almost 2 times more likely to demonstrate higher *Confidence*, and 92% more likely to demonstrate higher *Contribution* compared to youth with lower engagement. Compared to those with lower engagement, youth with higher engagement in 4-H had a 31% increase in their skills related to confidence, a 28% increase in their contribution, and a 23% increase in their caring.

Briefly describe how the broader public benefited from your project's activities.

Results of the annual evaluation indicated youth benefited in a variety of meaningful ways from their involvement in Utah 4-H. In addition, findings showed the impact of 4-H membership was greater for youth who were more involved in 4-H programs; as youth spent more years in 4-H and time on 4-H projects, they were more likely to demonstrate higher levels on all indicators of positive youth development. While these findings provide a glimpse of the role of 4-H on youth wellbeing, the intangible benefits of attending events, making friends, engaging with volunteer mentors, and gaining a sense of belonging may lead to additional benefits for youth.

With a rich history of serving as the youth branch of USU Extension, Utah 4-H aims to fulfill the land grant mission by giving all young people access to opportunity. Utah 4-H is actively exploring ways of moving youth through the 4-H Pathway to higher engagement while creating new connections with minority youth and underrepresented groups. There are continuing actions taken to strengthen partnerships with community grassroots organizations, active discussions on implementing culturally responsive education, and state-level discussions on diversity, equity, and inclusion. Ongoing efforts made to ensure an inclusive and welcoming environment in 4-H will benefit all youth as Utah 4-H works towards improving the wellbeing of youth.

Type	Projects / Programs
Projects / Programs without a Critical Issue	0
Not Provided	