Washington (Washington State University) Annual Report - FY2021

Report Status: Approved as of 09/16/2022

Contributing Organizations

Washington State University

Executive Summary

Overview

Washington State University (WSU) Agricultural Research Center (ARC - the Agricultural Experiment Station of the State of Washington) and Washington State University Extension collaborate to set consistent goals to conduct research beneficial to the citizens of Washington State and to extend relevant research results generated here and elsewhere, as well as research-informed programmatic engagement, to stakeholders within the state and beyond. We strive to create outcomes that improve the economic viability, environmental sustainability, community resilience, and quality of life for the people of the State, region and country. We recognize that we have unique land grant research and outreach missions to serve the people of Washington to enhance their quality of life and to evaluate both short and long-term consequences of potential policies, decisions and actions. The constraints of the COVID-19 pandemic have made clear the need for long-term attention to delivery of Extension and outreach-in-place for those who have limited ability to directly access WSU central locations. The ARC provides leadership in discovering and accessing knowledge by carrying out high quality research that contributes to a safe and abundant food supply; promotes the well-being of individuals, families, and communities; encourages sustainability of agricultural and economic systems; promotes energy innovation; and encourages careful stewardship of natural resources and ecological systems. WSU Extension creates programs with measurable deliverables and outcomes that leverage the research base of the University and academia to address primary and timely issues in ways that lead to economic development, improved policy and governance, sustainability and resilience as well as personal, family, and environmental wellbeing. The synergy provided by integrating research capacity, problem-solving skills and the statewide engagement of ARC and Extension enables unique capacity to address pressing issues and problems while recognizing different perspectives. This maximizes the delivery of valuable contributions to our residents and society.

The WSU ARC and WSU Extension have many natural and structural links. Washington State University faculty have responsibilities that include both research and outreach, with many having formal joint appointments across research, teaching and Extension. This is particularly true within the College of Agricultural, Human and Natural Resource Sciences (CAHNRS), which houses both ARC and Extension. More than 100 faculty with ARC or Academic positions hold partial Extension appointments. An additional approximately 80 faculty have full Extension appointments with a primary focus on off-campus program delivery, applied outreach and direct engagement. The focus of our joint efforts is to provide science-based knowledge and outreach programs to meet the primary needs of the people of Washington State. As part of this core mission, the ARC has made significant commitments to focus on fourteen high priority research areas that advance our land-grant mission in discovery and development research. These research areas are (1) precision and automated agricultural systems, (2) soil-plant interactions: chemical, physical, and biological processes, (3) sustainable food production from livestock, (4) developing food processing, safety, quality, and supply solutions for production of high quality and safe food, (5) promoting health and wellness of individuals, families, and communities, (6) reducing the impact of pests and diseases affecting Washington agriculture, (7) crop improvement and sustainable production systems, (8) enhancing sustainability across diverse agricultural systems, (9) natural resources, (10) integrated research and societal engagement to address global water challenges, (11) functional genomics in animal improvement, food safety, and human health, (12) integrated crop and weed management systems, (13) molecular plant sciences: plant productivity in a dynamic environment, and (14) bioenergy and biofuel.

WSU Extension delivers significant outreach related to five Critical Issue areas (1) sustainability, security and resilience; natural resource stewardship; (2) community economic development; (3) natural resources; (4) 4-H, youth development; and (5) fosterng a culture of health. The efforts of ARC and Extension are a committed element of a broader set of programs addressing issues in these areas that reside in the many WSU colleges and interdisciplinary centers, including CAHNRS; the Voiland College of Engineering and Architecture; the College of Arts and Sciences; the College of Pharmacy; the College of Veterinary Medicine; the new Elson Floyd College of Medicine,

and the Center for Environmental Research, Education and Outreach. Within Extension, specific examples of subject matter centers which conduct focused outreach efforts include the Food Systems Program, the Child and Family Research Unit, the AgWeathernet program, the William D. Ruckelshaus Center (a joint program with the University of Washington), the Division of Governmental Studies and Services, and the Metropolitan Center for Applied Research and Extension. Additionally, through close partnerships and collaborative agreements, our Research and Extension faculty also extend the research conducted by faculty at other regional centers of expertise, including among others the University of Washington, Oregon State University, and the University of Idaho. In 2021 Extension continued its initiative for developing stronger programmatic and project-based collaborations with the E.F. School of Medicine. In addition to activities focused on efforts to improve a statewide culture of health, on a pilot project to address agricultural worker behavioral health and suicide prevention, on response to a growing opioid crisis in the state, and more generally in connection to that college's unique distributed model for rural delivery of medical services and education to address health inequities, addressing the health concerns caused and made more immediate by the COVID-19 pandemic.

WSU researchers have garnered millions of dollars in extramural support to leverage their capacity grant funds into discovery and development research important to the citizens of Washington State. Between 2016 and 2020, WSU was the top university in the nation for total dollars awarded from USDA for research and development and over 80% of that total was from ARC and Extension faculty. The largest gift to Washington State University overall is still from the Washington Tree Fruit Commission, which approved check-off increases worth over $32 million over the eight years of the increased assessment for support of apple, cherry and pear research and extension. Other support in endowed professorships and research funding has been made available from organizations like the Washington Grain Commission (which has endowed several professorships at WSU and notably also donated over $5 million dollars to build a grains greenhouse), the Washington Potato Commission, the Washington Hops Commission and the Washington Wine Commission (which donated funding for the Ste. Michelle Wine Estates WSU Wine Science Center). There is a very vibrant relationship between WSU Research and Extension and numerous commodity- based entities in the state and region and we view this as a validation of the value placed on our efforts by our constituents and stakeholders. In addition, our county partners contribute more than $10 million annually - in cash and kind - to support county Extension operations.

There are numerous societal, environmental and scientific challenges that can be addressed by cutting-edge research and through the application of that research to the practical issues that face the residents of Washington. Every year we assess and evaluate our research portfolio to strategically prioritize our efforts to ensure the greatest impact is derived from both our research and extension programs. As a result, we can continue to deliver important outcomes including economic benefits to agricultural and natural resource-based industries, government entities, communities, and individuals. Additionally, our research and outreach help ensure that the people of Washington State maintain a high quality of life by limiting the negative impacts of chronic disease, addiction, food insecurity, and obesity, and with the goal of eliminating health inequities. Finally, our programs help ensure that the beauty of the state and its natural resources are sustained for future generations. Our annual Report of Accomplishments endeavors to summarize the inputs, outputs, and impacts of our work conducted during the year.

Critical Issue: Natural Resources

WSU scientists, faculty, and specialists will conduct research and extension programs leading to a better understanding of the interaction between human development and terrestrial, aquatic, and atmospheric conditions, investigate carbon sequestration innovations and technologies and improve soil health, manage and mitigate urban storm water runoff, restore riparian areas, provide wood and fuel using sustainable production practices, develop innovative mechanisms for revegetating mining sites, watersheds, and native prairies, and understand habitat requirements of key and endemic species. Extension specialists and their teams will work with researchers and local communities to develop customized, science-based solutions to local problems and to enhance understanding. The launch of the Washington Soil Health Initiative with legislative funding in 2022 is a strong example.

Critical Issue: Community and Economic Development

Communities, whether incorporated cities/towns, unincorporated villages, or communities of affinity, are essential to the well-being of individuals and the strength and success of society. Many rural communities in Washington have been negatively impacted by the constraints imposed by COVID-19, by climate change, and by perturbations in the world, national and local economies. Poverty and lack of access to critical elements of community resilience – such as capital, health care, high-speed broadband and living wage jobs – have challenged many rural communities across the state. Many -- if not all -- of the activities conducted by a land-grant institution such as WSU impact the development, strength and success of communities. WSU addresses community development, economic development and resilience both directly and indirectly through these efforts. Several large grants were awarded to WSU researchers in 2021 that seek to directly impact the rural economy of the state and region. This includes involvement in two Sustainable Agricultural Systems grants: one focuses on improving nutrition in the major grain crops of the region, which will thereby improve market share and the rural

economy, and the seccond focuses on development of a rural hemp bioeconomy for the west coast region. Several large Specialty Crop Research Initiative grants recently awarded to WSU focus on improving other major crops such as onions and hops, which again will lead to improved rural economy support for the state.

Critical Issue: Nutrition, Health and Wellness

WSU's expanding health sciences activities include Medicine, Nursing, Pharmacy, and others with a growing emphasis on meeting the needs of rural and underserved populations. In collaboration with health sciences WSU Extension will leverage health expertise of medical practitioners with community-based Extension programming and research to support a full-spectrum culture of health across Washington. This includes food and nutrition as essential element components of health, as well as education, training, and engagement on prevention, management of chronic conditions, and mental health promotion. Extension programs such as EFNEP and SNAP-Ed will be important elements of this effort, as well as prevention science, clinical intervention, and recovery support. Research efforts that seek to improve nutrition of important crops or that seek to understand how bioactive components from crops important to the state, such as raspberries, blackberries and apples, impact human health provide critical information needed for consumers to make the best food choices for themselves and their families.

Critical Issue: Strong Families and Youth Development

Youth are a critical component of our society: as the embodiment of our futures, as a gateway to stronger engagement with the adults in their lives, and as the locus for conducting the most effective proactive engagement strategies. With the new national emphasis on categorizing all youth-based activities as 4-H engagement, 4-H takes on even more importance. In order to address these multiple challenges and opportunities, in 2021 WSU Extension completed the change in status to recognize 4-H Youth Development as a separate program area within Extension, cutting across the three administrative Program Unit faculty units. This enables broader reach for research-based program delivery by extension professionals and supervised volunteers. These programs include 4- H club programs, and school and after school youth and family-based programs, such as Strengthening Families, that focus on enhancing preventive mechanisms. Washington State University Extension’s 4-H Youth Development weathered the storm of COVID, made more difficult by a Governor's mandate that all volunteers be vaccinated, and enters 2022 poised for growth wtih new energy and new audiences.

Critical Issue: Sustainability, Security and Resilience

The State of Washington, perhaps more than many other states, is subject to a wide array of environmental, economic, policy and political stressors and challenges. WSU seeks to assist in the effective prevention, response, mitigation, mediation, adaptation, and/or recovery from these challenges. WSU research and extension faculty are committed to the sustainability, security, and resilience of our families, communities, and industries many of which are dependent on sustainable agriculture, forestry and fisheries production. Basic research that increases the sustainability and security of the food, fiber, and fuel supply in the state of Washington while developing human capacity is of primary importance to our stakeholders and to our citizens. Research and Extension will work with industry and communities to co-innovate solutions to solve our biggest challenges, many of which are impacted by climate change. Many of the programs delivered by WSU Research and Extension specifically address the issues of sustainability, security and resilience, while many more have indirect impacts on those issues. Examples range from cropping systems extension to beginning farmer training to agriculture worker suicide prevention.

Merit and Scientific Peer Review Processes

Updates

None.

Stakeholder Input

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

None.

Methods to identify individuals and groups and brief explanation

None

Methods for collecting stakeholder input and brief explanation

None

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

Input from stakeholders strengthens our ability to assess need and demand, and to identify potential partners, identify emerging issues, and to evaluate the effectiveness of our research and extension programs in addressing these issues and needs as we move forward with Research and Extension activities, initiatives and programs. Our programs are directly influenced by stakeholder feedback and input.

The highest priority for our stakeholders is to support innovative research and extension outreach that addresses important issues that are critical to profitability, sustainability, and their health and well-being. Many stakeholders prioritize natural resources concerns related to water quality, water quantity, forest health, rangeland health, and stewardship. Local food systems and the desire for community connections with our food supply was another recurring theme, as was the desire to have us investigate new methods and practices for organic food production. Concerns over human health and diet, along with the growing incidence of obesity in our population were clearly stated as priorities and there was a desire to implement educational outreach to change behaviors. Consumer food safety education, positive youth development, and outreach to sustain rural communities were among several other stakeholder-defined issues that are being addressed by our current work. In 2020, other emerging issues such as the opioid crisis, access to affordable healthcare, and trust in government were made more immediate and exacerbated by the impacts of COVID-19.

Highlighted Results by Project or Program

Critical Issue

Community and Economic Development

Multistate Agricultural Literacy Research
Project Director
Jihyeong Son
Organization
Washington State University
Accession Number
1020884

Development of social media direct marketing curriculum for PNW small scale farmers

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

The project, titled "YouTube Live Video: Development of social media direct markting curriculum for PNW small scale farmers", assist in mitigating risks associated with market changes, by enabling producers to utilize social media to directly communicate with customers.

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.

I developed four learning mocules (to reduce 1, marketing risks, 2. legal risk, 3. human resources risks with video content. This project helped me to communicate with small farmers and skateholders in the agricultural businesses. based on these experiences, I was able to contribute agricultural literacy in U.S. In addition to that, the accessment of learning outcomes will be measured in 2022 with the modules, will help me to understand impact of these learning module and also undersearved communities' agricultural literacy.

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

The overall objective of this risk management project is to improve (1) small scale, (2) socially disadvantaged, and (3) beginning farmers' understanding and use of social media, differentiated direct marketing approaches, and marketing and networking to support local food system resiliency in Washington. Furthermore, it cultivates PNW farmers' ability to address copyright, regulatory and privacy issues to manage legal risk exposure and the use of social media. Lastly, the project aims to develop farmers' understanding of employee management to improve business and worker success around marketing.

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

The new attributes of this project, beyond previous projects, contribute to small farms' long-term economic sustainability. Also, the knowledge offered by this project is applicable to socially disadvantaged and beginning farms, and are not constrained geographically, since content will be available open source through YouTube.

Renewing an Agriculture of the Middle: Value Chain Design, Policy Approaches, Environmental and Social Impacts

Project Director
Marcia Ostrom
Organization
Washington State University
Accession Number
1014196

Renewing an Agriculture of the Middle: Value Chain Design, Policy Approaches, Environmental and Social Impacts

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

Our project addresses the loss of small and mid-scale commodity farms and farmland protection by exploring market-based innovations and policy solutions.

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.

We carried out the following research and extension to meet our three major objectives:

(1)Investigate key factors that influence economic performance and viability of mid-scale farms/ranches and their supply-chain partners.
(2) Identify and assess the environmental and natural resource contributions of mid-scale supply chains.
(3) Identify and assess the possibilities of mid-scale supply chains to contribute to community goals and needs.

Under Objective 1:

a. Analysis and write-up of article featuring cider apple grower survey results covering the characteristics, research and extension needs, and goals of cider apple growers was finalized and accepted in the Horticultural Technology Journal cited here.

b. Interview instrument and list of cider distributors for interviewing in four states was finalized.

c. My graduate student interviewed distributors across four states and transcribed the notes.

Under Objective (2):

a. Data from our national survey of Agriculture of the Middle producers was analyzed for environmental attitudes and associations with marketing systems. Our team prepared a paper summarizing these results and used them to answer outstanding questions in our Values-Based Food Supply Chain literature. The paper was accepted and published in the Journal of Agriculture and Human Values cited here.

Under Objective (3):
a. We continue to study the racial and social equity aspects of Extension programs that serve agricultural producers producing foods for value-added regional marketing systems using our program evaluations. I wrote a paper that was submitted to the Journal of Agriculture, Food Systems and Community Development and received a recomendation to publish with minor revisions.

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

Our target audience is small to mid-sized farmers with total sales from $10,000e $500,000; women and minority farmers, Latino/a farmers, value-added food businesses and alternative marketing programs, university faculty, agricultural professionals, conservation programs, policy-makers, food consumers, and community development organizations. Our research findings were utilized to organize extension programs, make conference presentations, and publish articles. Our extension program evaluations show that farmers have made significant knowledge gains from participation.

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

Understanding ways to keep small and mid-sized farmers in business should provide more secure access to quality, healthy foods at a regional level. Our research indicates that consumer demand for local, healthy farm products has remained robust through Covid-19.

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.

Our multistate NC 1198 Renewing an Agriculture of the Middle project held its annual meeting via zoom from October 4-5, 2021 led by our Chair Becca Jablonski from Colorado State. This was an important opportunity for professional development as it convenes researchers from around 15 states to report and confer about their worke Updates are provided on new grant opportunities, national research, and state-level research projects. We also heard presentations by USDA representatives and policy experts to learn about relevant NIFA AFRI program developments and new research initiatives relevant to the mid-scale farm and marketing sector as well as social equity in agriculture.

In addition we disseminated our findings in the following ways:

1. I developed and presented a panel session with our WSU Food Systems Team, farmers, and community partners on "Inclusive Pedagogies for Growing Just Food Systems from the Ground Up: Collaborative University-Farmer Education Partnerships" at the virtual Agriculture, Food, and Human Values Society Annual Meeting, Virtual, June 10.

2. I developed and submitted a panel session with my NC 1198 colleagues from OSU and UC-Davis that was accepted for the 2021 National Farm Viability Conference on "Building social equity into Agriculture and Food Systems Extension." This event is primarily for agricultural professionals and farmers.

We shared our findings through developing three publications:

Peterson, H., Feenstra, G, Ostrom, M., Tanaka, K, Brekken, C. and *G. Engelskirchen (2021). The Value of Values-based Supply Chains: Farmer Perspective, *Agriculture and Human Values,* August. https://doi.org/10.1007/s10460-021-10255-5

Ostrom, M., Conner, D., Tambet, H., *Smith, K., Sirrine, J., Howard, P., and M. Miller *(Accepted in 2021).* Apple Grower Research and Extension Needs for Craft Cider, *HortTechnology* 32(2). https://doi.org/10.21273/HORTTECH04827-21

Ostrom, M. *(In Revision).* Rediscovering the Civic Roots and Egalitarian Ambitions of Land-grant University Agricultural Extension. *Journal of Agriculture, Food Systems, and Community Development* #2022-2356.

During the next reporting period we plan to analyze our data from interviews with hard cider distributors and retailers and survey consumers in four states about purchasing priorities for value-added ciders.

We also plan to do a national panel survey on extension priorities related to values-based food production and distribution and equity in access to extension programs.

Critical Issue

Natural Resources

Microirrigation: A Sustainable Technology for Crop Intensification and Improved Crop Productivity

Project Director
Pete Jacoby
Organization
Washington State University
Accession Number
1021468

Subsurface Microirrigation in Vineyards

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

A novel form of subsurface microirrigation is being developed through research and demonstration activities in commercial vineyards through collaboration with winegrowers in several states. To date activities have been initiated in Washington, Oregon, California, Arizona, Texas and Kansas. Grower/cooperators are implementing the Direct Root-Zone method of subsurface microirrigaton in collaboration with the program leader, Jacoby, and sharing results from their particular location for further advancement of this technique.

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 results of research performed has been published in high impact scientific journals, a number of trade magazines that directly reach practicing winegrowers, as well as a number of broadcasted radio interviews and podcasts. These publications have resulted in growers directly contacting the project leader for additional information. These exchanges have resulted in additional on-site demonstrations of the DRZ technique and collaborative installations in newly planted vineyards.

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

The target audience are winegrowers using irrigation and stiving to become more sustainable in the use of limited water resources. While the expansion of collaborators has been rapid, the results of water savings will be slower to emerge as many of these vineyards are newly planted. Results of water savings from established vineyards has demonstrated that savings of 40-50 percent can be expected through use of DRZ subsurface drip irrigation.

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

Most vineyard production of winegrapes occurs within more arid parts of the western U.S. where water resources for agriculture can be limited and even threatened by competing uses of water, especially during periods of drought, such as recently experienced in California, the nation's leading state for winegrape production. Wine producers and the general public are becoming increasingly impacted by water restrictions, a trend heightened by the threats of climate change.

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.

There have been few problems experienced in use of the DRZ technique. The program received a commercialization grant from WSU and this resulted in a potential client to advance an effort to mass produce the irrigation delivery device and began a public demonstration program as a 501c3 enterprise in California. The effort is currently very new but some leading vineyards are joing this effort to find efficient ways to save water while increasing grape and wine quality. By the next reporting period, results from these collaborative efforts across several states will be available from the 2022 growing season.

High Impact International Peer Reviewed Journals

Chandel, A.K., L.R. Khot *, B. Molaei, R.T. Peters, C.O. Stöckle, **P.W. Jacoby**. 2021. High-resolution spatiotemporal water use mapping of surface and direct-root-zone drip irrigated grapevines using UAS-based thermal and multispectral remote sensing. *Remote Sens.* 13, 954. https://doi.org/10.3390/rs13050954

Ma, X.C., and **P.W. Jacoby**. 2021 Optimizing water use efficiency for production of Chardonnay grapevine (*Vitis vinifera* L.) in silt loam soils through a novel subsurface irrigation. *Water* (submitted for review).

Extension Outreach, Popular Press, Symposium Proceedings and Conference Abstracts

Jacoby, P.W., LR. Khot. 2021. *Advancements of sensor-based water management to maximize crop water use efficiency in conjunction with direct root zone (DRZ} subsurface drip irrigation*. ASABE /AI 6th Decennial Irrigation Symposium, San Diego, CA, Dec. 5-6. DOI: https//doi.org/10.13031/ irrig.2020-045 Paper Number:20-045

Jacoby, P.W., M. Brain. 2021. *Sub-surface micro-irrigation in vineyards*. Podcast #101: Sustainable Winegrowing with Vineyard Team, Atascadero, CA. https//www.vineyardteam.org /.Qodcastl? id=8 77

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

Project Director
Markus Flury
Organization
Washington State University
Accession Number
1020917

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.

Microplastic pollution in terrestrial environments is pervasive problem. While much is known about microplastic pollution in aquatic ecosystems, little is known about fate and transport of microplastics in soils. In this project we investigate distribution, transport, and toxicity of microplastics in 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.

Goal (1): To improve our fundamental understanding of soil physical properties and processes, and how they interact with other environmental and biogeochemical processes across various spatial and temporal scales.

Biochar is being used as a soil amendment to improve soil hydraulic properties. It has been reported that biochar increases plant-available water, particularly in coarse-textured soils; however, effects on fine-textured soils are less pronounced. We quantified the effects of biochar particle size on plant-available water in sand, silt loam, and clay soils. Our results show that biochar amendments increased the plant-available water (when expressed gravimetrically) of all three soils, particularly at the highest biochar application rate. Although the absolute increase in plant-available water was largest for the silt loam soil, the relative increase of plant-available water was greater for the sand than for the silt loam and clay. Our results show that biochar is a beneficial soil amendment to increase water holding capacity for soils.

Goal (2): To extend our knowledge of scale-appropriate methodologies to improve stakeholder-management of soil and water resources that benefit agricultural, natural resource and environmental sustainability.

There is an increased interest in the use of soil-biodegradable plastic mulch due to limited disposal options for conventional polyethylene mulch. However, information about the impact of continuous use of soil-biodegradable plastic mulch on the environment is limited. We investigated the effects on soil and groundwater quality from the use of soil-biodegradable plastic mulches for crop production for four consecutive seasons. Within the four-year period, the soil-biodegradable plastic mulches had overall positive effects on soil and groundwater quality, except for reduced burst microbial respiration, which was more pronounced in Mount Vernon.

We also investigated how biodegradable plastic mulches deteriorate and degrade in a natural soil environment. We characterized and quantified the chemical changes occurring in plastic mulches overtime when exposed to sunlight and soil conditions. We found that the changes of physicochemical properties were affected by polymeric composition, and faster degradation occurred in warmer climates. These results help to better design biodegradable plastics for optimal in soil degradation.

Goal (3): To develop and evaluate new instruments and analytical methods to connect our understanding of mass and energy transport in soil at different scales to environmental transformations.

The amount of plastic particles in terrestrial ecosystems is not well known, not only because it is difficult to ex-tract and identify plastic particles from terrestrial samples, but also because it is challenging to take representative samples from soils or sediments. We simulated how to take representative terrestrial samples to quantify plastic particles, and we evaluated the accuracy (error) of reported plastic concentrations in the literature. We developed a new method to take representative sample from the field. This method consists of taking replicated samples with each sample as large as possible (e.g., 1 m × 1 m) rather than multiple small cores, and then reduce the soil volume by the quartering method. This new method will allow for standardized soil sampling for future studies.

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

Our target audiences are Students, Scientific peers, Department of Energy, Environmental Engineering and Consulting Companies, Farmers, Industry, Biosolids, Compost, and Plastic Professionals. These have benefited through providing educational opportunities (3 graduate students are being trained), providing new methods for research (scientific peers), providing background data on plastic concentrations in soils (Department of Energy, Environmental Engineering and Consulting Companies, Farmers), quantifying benefits of biochar and compost as soil amendments (Biosolids, Compost), and providing guidelines for improvements of biodegradable plastic mulches (Plastic Professionals).

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

We provide, for the first time, quantitative data on plastic concentration in soils. As there is little information about how much plastics is in soils and how toxic that could be; this is important information for the broader public. We also provide justification for the use of biodegradable plastic in agriculture, and we argue that conventional plastics should be replaced with biodegradable plastics for single-use items, such as plastic mulch films. We have disseminated this information to the broader public via several podcast and newspaper interviews.

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.

1. Yu, Y., D. E. Griffin-LaHue, C. A. Miles, D. G. Hayes, and M. Flury, Are microplastics from biodegradable plastic mulches an environmental concern?, J. Hazard. Mat. Adv., 4, 100024, doi.org/10.1016/j.hazadv.2021.100024, 2022. (doi.org/10.1016/j.hazadv.2021.100024)

2. Yu, Y., and M. Flury, How to take representative samples to quantify microplastic particles in soil?, Sci. Total Environ., 748, 147166, doi.org/10.1016/j.scitotenv.2021.147166, 2021. (doi.org/10.1016/j.scitotenv.2021.147166)

3. Yu, Y., and M. Flury, Current understanding of subsurface transport of micro- and nanoplastics in soil, Vadose Zone J., 20, e20108, doi.org/10.1002/vzj2.20108, 2021. (doi:10.1002/vzj2.20108)

4. Yu, Y., M. Elliott, I. Chowdhury, and M. Flury, Transport mechanisms of motile and non-motile Phytophthora cactorum zoospores in unsaturated porous media, Water Resour. Res., 57, e2020WR028249, doi.org/10.1029/2020WR028249s, 2021. (doi:10.1029/2020WR028249)

5. Flury, M., and R. Narayan, Biodegradable plastic as integral part of the solution to plastic waste pollution of the environment, Current Opinion Green Sustainable Chem., 30, 100490, doi.org/10.1016/j.cogsc.2021.100490, 2021. (doi.org/10.1016/j.cogsc.2021.100490)

6. Yang, W., T. Qu, M. Flury, X. Zhang, G. Sigmund, J. Shang, and B. Li, PAHs sorp- tion to biochar colloids changes their mobility over time, J. Hydrol. (Amsterdam), 603, 126839, doi.org/10.1016/j.jhydrol.2021.126839, 2021. (doi.org/10.1016/j.jhydrol.2021.126839)

7. Schulze-Makuch, D., D. Lipus, A. Airo, F. Arens, M. Baque, T. L. Bornemann, J.-P. deVera, M. Flury, J. Fr ?osler, J. Heinz, Y. Hwang, S. P. Kounaves, K. Mangelsdorf, R. U. Meckenstock, M. Pannekens, A. J. Probst, J. S. Saenz, J. Schirmack, M. Schloter, P. Schmitt-Kopplin, B. Schneider, J. Uhl, G. Vestergaard, B. Valenzuela, P. Zamorano, and D. Wagner, Microbial hotspots in lithic microhabitats inferred from DNA fractionation and metagenomics in the Atacama Desert, Microorganisms, 9, 1038, doi.org/10.3390/microorganisms9051038, 2021. (doi.org/10.3390/microorganisms9051038)

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Closing Out (end date 09/07/2023)

Integrated Research and Societal Engagement to Address Global Water Challenges

Project Director

Jonathan Yoder

Organization

Washington State University

Accession Number

1015637

Integrated Research and Societal Engagement to Address Global Water Challenges

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

The overarching goal of this project is to improve water use efficiency and water quality management through the pursuit of various objectives, including (a) research and extension efforts to improve irrigation water management to reduce water use, improve crop yields, decrease costs, and improve water quality; (b) Stormwater Management to minimize flooding, protect clean water, and promote thriving ecosystems; and (c) Integrated Water management to address complex integrated water management issues by incorporating climate change, analyzing resilience, and quantifying economic tradeoffs.

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) Irrigation findings of importance: Many people argue that water losses from sprinklers suppress crop water use downwind and thus are not truly losses. We showed that this is true. However, the suppression is so small, especially in comparison to the variation in water losses due to other factors as to be practically negligible. The water losses from sprinklers are large, permanent (leave the drainage basin), and often ignored. A novel form of subsurface microirrigation is being developed through research and demonstration activities in commercial vineyards through collaboration with winegrowers in several states. To date activities have been initiated in Washington, Oregon, California, Arizona, Texas and Kansas. Grower/cooperators are implementing the Direct Root-Zone method of subsurface microirrigaton in collaboration with the program leader, Jacoby, and sharing results from their particular location forfurther advancement of this technique.

(b) Stormwater management: New Baysian modeling methods were developed to assess impacts of pesticides on salmon.

(c) Integrated water management: A major report on tong-term water supply and demand in the Columbia Basin was delivered, as well as a synthesis of existing science for water supply, demand, and insecurity for the Skagit Basin of Northeastern Washington. These two project reports represent multidisciplinary integrated water science and management deliveries that benefit water resource managers and water rights owners.

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

(a) Irrigation: For a subset of this work, the target audience are winegrowers using irrigation and stiving to become more sustainable in the use of limited water resources. While the expansion of collaborators has been rapid, the results of water savings will be slower to emerge as many of these vineyards are newly planted. Results of water savings from established vineyards has demonstrated that savings of 40-50 percent can be expected through use of DRZ subsurface drip irrigation.

(b) Stormwater Management: Two nontechnical articles focus on positive perspectives and approaches to understand whether urban/peri-urban stormwater runoff affect agricultural soil health, and discuss pathways to mitigating stormwater runoff water quality problems.

(c) Integrated water management: The integrated science reports provide on the one hand long-term planning information for watersheds in the Columbia River Basin to facilitate infrastructure and administrative planning for the effects of climate and demographic change. The Skagit project provided a basis for identifying knowledge gaps that would help in water resource management at the basin scale, and is being used to identify new research to fill these knowledge gaps.

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

(a) Irrigation: Most vineyard production of wine grapes occurs within more arid parts of the western U.S. where water resources for agriculture can be limited and even threatened by competing uses of water, especially during periods of drought, such as recently experienced in California, the nation 's leading state for wine grape production. Wine producers and the general public are becoming increasingly impacted by water restrictions, a trend heightened by the threats of climate change.

(b) Stormwater Management: Stormwater impacts on water quality affects the general public through surface and groundwater impacts, which may affect drinking water supplies as well as ecosystem services such as salmon habitat. In Washington State, the Puget Sound is heavily impacted by stormwater runoff from Seattle and surrounding municipalities. A better understanding of the pathways to stormwater effects and the options for mitigating water quality impacts of stormwater runoff have broad public impacts.

(c) Integrated water management: The broader public has an interest in how water managers manager public water resources, how water rights holders utilize their water rights, and how municipalities utilize their water through public utilities. Beyond that, there is strong public interest in water supply availability for all water uses and how they are changing due to climate change.

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.

Irrigation; wine grape activities: There have been few problems experienced in use of the DRZ technique. The program received a commercialization grant from WSU and this resulted in a potential client to advance an effort to mass produce the irrigation delivery device and began a public demonstration program as a 501c3 enterprise in California. The effort is currently very new but some leading vineyards are joining this effort to find efficient ways to save water while increasing grape and wine quality. By the next reporting period, results from these collaborative efforts across several states will be available from the 2022 growing season.

Critical Issue

Nutrition, Health and Wellness

Promoting Health and Wellness of Individuals, Families, & Communities

Project Director

Y Sano

Organization

Washington State University

Accession Number

1016109

Progress report on Personal Protective Equipment (PPE) and Rural Resilience studies

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

Creating a healthy nation is a top priority in the United States. This Washington State University Hatch project titled, Health & Wellness Umbrella Project organizes diverse research projects conducted by WSU faculty from multiple disciplines and intends to collectively advance health- related knowledge and scholarship. This collaboration will also translate newly gained knowledge to educational and community-based activities.

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 2020-2021 project year, there were two areas that we focused on: 1) the development of Personal Protective Equipment (PPE), and 2) examining rural resilience among low-income families.

For the study 1), we conducted laboratory experiments to manufacture materials with advanced functions into fibers for smart sensing textiles. Polymers with advanced functions, such as electric conductivity and chemical sensing ability, are often difficult to process. We develop novel processing techniques to produce textile fibers using these functional materials and ensure the fibers meet the basic textile requirements on durability and washability in addition to the advanced functions.

For the study 2), we made solid progress fulfilling the project's objectives. Research and outreach activities mined secondary data from community datasets and previously collected project datae A strategy and protocol were developed to collect Community Key Informant data virtually from community key informants in Klickitat and Grant counties. We have identified some nascent themes which emerged from our Community Key Informant (CKI) interviews. In the next project year, we will further analyze the data and translate our findings to broader audience.

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

The target audiences of the PPE project include pesticide handlers and other personnel who are exposed to various physical, chemical, or biological hazards. The functional fibers developed from this project can be integrated into protective apparatus to sense human vital signs and environmental hazards to enhance the safety of the project's target audiences.

The Rural Resilience project adds to the understanding of the experience and expression of resilience of families living in rural poverty. The proposed collecting of unique quantitative and qualitative datasets will capture family characteristics as well as the resources available to them through their communities. The knowledge generated from this project has direct implications for informing family-focused and community level programs intended to foster resilience.

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

We communicate our findings through peer-reviewed publications, book chapters, conference presentations, webinars, and other outreach activities. The broader public benefitted from our research in following ways:

- The functional fibers developed from the PPE project can be processed into sensors that are integrated into everyday clothing for continuous human vital sign sensing.

- Rural Resilience project improves knowledge of community-level assets and challenges and understanding of factors and processes of resilience at the family level. This increases community capacity by informing community stake holders.

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.

Major change:

One of our original team members, Dr. Cory Bolkan, no longer participates in this collaborative project. This is because a multi-state research project Dr. Bolkan was involved in was not renewed as a project. As a result, our project has only two active studies conducted by Dr. Hang Liu (PPE project) and Dr. Yoshie Sano (Rural Resilience project).

Publications:

1. Cho, H. S., Jang, E., Liu, H., & Cho, G. (2021). Applicability of poly (3, 4- ethylenedioxythiophene): Poly (styrene sulfonate) impregnated polyurethane nanoweb as a transmission line for smart textiles. *Textile Research Journal*, *91*(11-12), 1253- 1262.

2. Liu, W., Zhong, T., Liu, T., Zhang, J., & Liu, H. (2020). Preparation and characterization of electrospun conductive Janus nanofibers with polyaniline. *ACS Applied Polymer Materials*. https://doi.org/10.1021/acsapm.0c00364

3. Cho, H. S., Jang, E., Liu, H., & Cho, G. (2020). Applicability of poly (3, 4- ethylenedioxythiophene): poly (styrene sulfonate) impregnated polyurethane nanoweb as a transmission line for smart textiles. *Textile Research Journal*, 0040517520975633.

4. Sano, Y., Greder, K., & Mammen, S. (2021). Development of food security messages with rural, low-income mothers. Special Issue on Rural Low-Income Families (Berry, A. and Greder, K., Eds.), *Forum on Family and Consumer Issues*, 23(1). Online journal. First made available March 2021.

5. Sano, Y., & Mammen, S. (In Press). Mitigating the impact of the Coronavirus pandemic on rural low-income families. *Journal of Family and Economic Issues*.

6. and Obesity?

Project Director
Meijun Zhu
Organization
Washington State University

Accession Number
1014898

Dietary alpha-ketoglutarate and intestinal health

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

Inflammatory bowel diseases (IBDs) are chronic and relapsing intestinal inflammation common in Western societies. As an intermediate of the Krebs cycle, the alpha-ketoglutarate (aKG) content in foods varies dramatically, but the roles of aKG in colits protection is unclear.

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.

To test the beneficial effects of dietary aKG against the IBD, we conducted a mouse study using a dextran sulfate sodium (DSS) induced - colitis model. We found that dietary aKG supplementation decreased DSS-induced body weight loss, gross bleeding, fecal consistency score, and disease activity index. Additionally, aKG supplementation ameliorated mucosal damage, suppressed gut inflammation, and improved epithelial structure. In summary, aKG supplementation protects against epithelial damage and ameliorates DSS- induced colitis.

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

Our data suggest that aKG is a novel bioactive compound, which can improve gut epithelial health. Such knowledge will be useful for the food industry and agricultural producers to develop strategies to increase aKG content in foods.

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

Our data show that intake of foods enriched with aKG or aKG supplementation can be an alternative approach for the prevention or treatment of colitis and improve the overall health of the gut.

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.

Bravo Iniguez, A., and M. J. Zhu. 2021. Hop bioactive compounds in prevention of nutrition-related noncommunicable diseases. *Critical Reviews in Food Science and Nutrition,* 61: 1900-1913.

Sun, Q., M. Du, D. A. Navarre, and M. J. Zhu. 2021. Cooking methods on bioactivity of polyphenols in purple potatoes. *Antioxidants,* 10: 1176.

Tian, Q., A. Bravo Iniguez, Q. Sun, H. Wang, M. Du, and M. J. Zhu. 2021. Dietary alpha-ketoglutarate suppressed dextran sulfate sodium induced colitis associated glycolytic metabolism. *Molecular Nutrition and Food Research,*65: 2000936.

Tian, Q., J. Zhao, Q. Yang, B. Wang, J. Deavila, M. J. Zhu, and M. Du. 2020. Dietary alpha-ketoglutarate promotes beige adipogenesis and prevents obesity in middle-aged mice. *Aging Cell*, 19: e13059.

Tian, Q., Z. Xu, X. Sun, J. Deavila, M. Du, and M. J. Zhu. 2020. Grape pomace inhibits colon carcinogenesis by suppressing cell proliferation and inducing epigenetic modifications. *Journal of Nutritional Biochemistry,* 84:108443.

Critical Issue

Sustainability, Security and Resilience

Facilitating Registration of Pest Management Technology for Specialty Crops and Specialty Uses

Project Director
Douglas Walsh
Organization
Washington State University
Accession Number
1025824

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.

U.S. Department of Agriculture's Interregional Research Project #4 (USDA/IR-4) is a federal/state/private cooperative that aspires to obtain clearances for pest control chemistries on specialty crops. I serve as the State Liaison from Washington State to the to the USDA/IR-4 program and represent the IR-4 program on the Washington State Commission on Pesticide Registration. My laboratory serves as a Field Research Center for crops produced in Eastern Oregon, Eastern Washington, and most of Idaho.

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 WSU IR-4 magnitude of pesticide residue program at WSU completes trials that are all conducted under EPA mandated good laboratory practices. These data are used in petions for pesticide tolerances on specialty crops produced in the Pacfic Northwest.

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

Specialty crop producers have benefitted from access to newer reduced risk and more selective pesticides compared to traditional broad-spectrum pesticide chemistries.

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

Food and beverage consumers are provided with an affordable, wholesome and safe food supply.

Enhancing the Sustainability of Beef and Dairy Cattle Production through the Reduction of Production and Human Risks

Project Director
Kristen Johnson
Organization
Washington State University
Accession Number
1025787

Enabling Livestock Producers and Others to Create a Sustainable Future through Applied and Fundamental Research

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

The goal of this project is to enable livestock producers, and others with interest in the livestock industry, to create a sustainable future through applied and fundamental research. The expected outcome of this work is fundamental knowledge in the genomics of reproduction, disease susceptibility, the role of the immune system in nutritional requirements, and the role of pest birds in the transmission of disease. This work will be linked to stakeholders by application of the knowledge

gained through economic assessment, recommendations for new management strategies, generation of new tools and education of workers. All of the work conducted will be done to mitigate risk in livestock production and create a sustainable future. To accomplish our goal, we have developed several objectives.

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.

1. Previously, we have identified DNA regions that are associated with maintenance of pregnancy in different breeds (Holstein, Angus and Salers) and ages of cows. This year we further evaluated these regions at the molecular level to identify all DNA changes in and around them in 24 Holstein, and 7 Salers ,;1nd Angus/Salers cattle. This was done to determine how these DNA regions might be affecting fertility and aid us in predicting cattle that were most likely to maintain their pregnancy. The evaluation of these regions required additional training of our staff and a graduate student, which is now nearing completion. This will enhance their ability to conduct genetic studies in the future after an initial association is found with a trait.

2. To combat BRD using a synergistic approach, we have identified regions of DNA that are predictors of beef and dairy cattle that are more likely to become affected with BRO in the West, Northwest and Southwest United States. The current study is to validate these DNA regions in a Midwest dairy calf population. As selection will need to account for the BRO pathogens the animals are exposed to, this study will identify if the BRO pathogens that are predominant in the Midwest differ from those found in our previous studies in other US locations. In 2020, the study was initiated by collecting samples from Holstein calves in Wisconsin. Unfortunately, this site was discontinued due to personnel challenges and COVID at the Wisconsin dairy. We have recently re-started the study at a site in Ohio in October. So far, the collection of samples is going well and we anticipate that the sample collection will be complete by the end of next year allowing analysis of these DNA regions to begin. The identification of pathogens in the calves sampled is already being compiled and the calf DNA is being processed as the samples are received. The initial pathogen and genotyping analyses are anticipated to begin at the end of next year.

3. Examination of the data indicates breed differences between the Angus and Hereford populations. The Angus population had eight gene loci that were associated with the RFI phenotype while the Herefords had six loci and they did not overlap. This same result was true for the GSEA-SNP analysis. The Hereford data indicated that a molecular mediator of immune response was one of the most significant gene sets. Network analysis also illustrated important genes and gene regulators associated with immune function in both breeds. These results begin to identify areas in which the regulation of the immune system is important in the efficiency trait.

4. Vermiculture, a manure handling technique that relies on earthworms degrading organic matter to reach a stable state, is one such option. Earthworms use the organic matter in manure to establish a community and develop worm castings that optimize nutrient density. The objective of an ongoing study is to examine the nutrient transformations from a vermifiltration system on a commercial dairy farm. The substrate to the worm beds is the liquid effluent after solids separation. Liquid flows continuously through the beds and is collected at an outflow port where it is stored. Nutrient composition from the influx and outflow ports are monitored as are methane (CH4), nitrous oxide (N2O) and ammonia (NH3) emissions. Real time gas analyzers in conjunction with flux chambers recorded N2O and CH4 concentrations and fluxes were calculated. Ammonia (NH3) was measured using honeycomb denuders. Preliminary data indicates reductions of: 25% in potassium, 96%, in phosphorus, 99% in total suspended solids, 92% in volatile solids and 92% reduction in total Kjeldahl nitrogen. Preliminary emissions data indicate that emissions from vermifiltration are lower than emissions reported from traditional lagoon systems. N2O and CH4 emissions were higher in a wet location in the system compared to a dry site. Average NH4 concentrations were high and higher at wet locations. Decreasing GHGs and NH3 emissions from manure handling systems will allow producers to reduce their carbon footprint and assist in their goal of sustainability.

5. We purchased and distributed 40 American kestrel nest boxes to seven Washington dairy farms. All nest boxes will be installed by April 2022 to ensure they are available for the 2022 American Kestrel breeding season. The nest boxes will be monitored for occupancy rates. We also developed a partnership with a laser company to install lasers in free stall

dairy barns to measure their efficacy in deterring pest birds. We will also record dairy cattle behavior pre- and post-installation of the lasers to determine whether dairy cattle are impacted by the use of lasers in free stall barns. Our Extension program efforts (factsheet publication, workshops, and educational exhibits) have increased awareness of alternative pest bird deterrence methods and we are noticing an increase in the number of farmers interested in adopting these practices.

6. We worked in collaboration with WA Department of Natural Resources and the Washington Cattlemen's association to establish 2021 grazing permit and lease rental rates. This involves data collection on WA cattle prices to calculate formula determined rental rates for public lands. Additionally, we developed a project and received US Forest Service funding ($102,857) in 2021 to evaluate climate impacts on grazing systems. This research develops rangeland analogs to evaluate climate impacts on rangelands. Additionally, this project will develop a cattle market model to evaluate drought induced price impacts. In collaboration with Paul Kuber and Juan Villalba, Utah State University, we submitted the proposal, Novel Integrated Approaches for Medusahead Control in Western Rangelands, $349,629 to USDA WSARE.

7. We distributed a survey about dairy cattle handling safety and training to Washington and Oregon dairy farmers. The survey was distributed via email and in-person at the annual dairy industry meetings. Survey results were analyzed and a scientific journal article reporting these results is currently in progress. Working in partnership with the University of Washington Pacific Northwest Agricultural Safety and Health Center, our team delivered dairy cattle handling safety training to over 120 dairy employees using two different training styles. We collected pre- and post-training knowledge assessments from all employees to analyze the effectiveness of each training style. Our Extension program efforts (workshops, Extension articles, and educational exhibits) led to the development of a regional partnership with Washington, Oregon, and Idaho dairy associations.

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

The target audience for identifying loci associated with feed efficiency, disease and fertility are breed associations, commercial genotyping companies that provide estimated progeny differences (EPDs) to breed associations, producers and breeding companies that provide semen for artificial insemination. The identification of loci associated with production and health traits provides the industry with the genomic regions to calculate EPDs in cattle genotyped. These EPDs are used to select and mate cattle to produce efficient feedlot cattle to feed the United States. Animals that are more efficient produce more meat with less feed than inefficient animals resulting in increased environmental stewardship, sustainability and profitability. Cattle producers also benefited from our work determining fair grazing rates that balance cattlemen perspectives with managing public lands for multiple use benefits that includes generating funds for education. Rangeland research was initiated this year so results and outcomes from this project is not developed for public dissemination.

Our target audience for this project is primarily dairy farmers, employees, veterinarians, and consultants. However, other livestock and crop industries could also benefit from our pest bird management research and employee safety training program. To date, our target audience has increased knowledge about alternative pest bird management methods and safe cattle handling practices. Dairy farmers have the opportunity to test low-risk alternative pest bird management methods on their farms and may observe a decrease in losses from pest bird damage. The data from the evaluation of vermiculture to reclaim nutrients from wastewater indicates that the system does alter the composition of the waste water and does alter the greenhouse gas emissions. Pacific Northwest dairies are interested in this data not only so they may reduce the nitrogen and phosphorus in waste water, but also because the process results in co-products (e.g. worm castings) but also because it may be possible to enter carbon markets. The dairy farmers and employees that participated in our safety trainings were equipped with all the tools they need to share the safety training content with co-workers. The safety culture on participating farms has improved, including communication about safety topics between dairy employees and owners.

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

Genomic selection is used to more accurately predict animal performance. The broad benefits of genomic selection (for reduction of the prevalence of BRD, pregnancy loss and an increased feed efficiency for cattle) are to improve animals so that consumers enjoy lower cost of food and food security with enhanced animal welfare and reduced environmental impacts. For producers, genetic progress in health and feed efficiency means that cattle are healthier, suffer disease less, require less health intervention with anti-microbials and produce more product with fewer animals. Animals that are more efficient and healthy result in increased opportunities for environmental stewardship, sustainability and profitability for the cattle industry and the US economy. Sustainable beef production systems include efficient nutrient use by the animal and healthy animals able to meet the challenges of environmental pathogens. The general public demands appropriate animal welfare and control

of nutrient losses. The information collected in this project will benefit the general public as they evaluate their food supply and understand the commitment of the beef industry to selection of healthy, efficient animals. The public benefits from both well managed rangelands and sustainable beef production systems. In 2021 we published the results from evaluating the economic contributions of the Washington Beef Sector which informs the public and policy makers of the beef sector's economic size and employment numbers.

The broader public has concerns about dairy employee and cattle well-being. Dairy consumers want reassurance that their dairy products come from farms that care about employee and cattle well-being. Additionally, consumers care about the environmental impacts of dairy farming. They want to see dairy farmers make efforts to farm sustainably and make concerted efforts to preserve nature. Our project addresses both consumer concerns. Our Extension program includes public events that allow citizens the opportunity to learn about the dairy industry and livestock production. Reduction in greenhouse gas emissions, water reclamation and closer linkages between dairies and surrounding cropland to enhance soil characteristics make the examination of vermiculture systems important to the broader public who is interested in sustainable food production systems and circular economies.

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.

We encountered no major changes or problems in our approach for much of this project. Two PhD students, two MS students, and nine undergraduate researchers participated and assisted with this project. Results from this project were disseminated through national meeting presentations, scientific journals, Extension articles, workshops, educational exhibits, and demonstrations. These avenues for dissemination allow our target audience, as well as the general public, to learn about our findings.

The study to reduce embryonic loss in cattle is currently characterizing the DNA sequence variants of 123 loci that were found to be associated with embryonic loss in more than one study or in more than one breed. Whole genome sequencing was performed on dairy and beef cattle to identify DNA variants. DNA variants in the 123 loci associated with embryonic loss are being further characterized. Regions within these loci that are likely to result in functional gene expression differences are being identified and DNA variants within these regions are being scrutinized to determine the likelihood that they would result in gene expression or "functional" changes. Identifying functional changes associated with embryonic loss may lead to the discovery of causal mutations that lead to embryonic loss. This will enable greater prediction accuracy for assessing embryonic loss and a better understanding of the mechanisms involved. This process was delayed as this analysis was initially to be completed by collaborators, but we have now taken on this task. At this time, all sequence variants have been identified and about a third of the putative functional regions have been characterized. This year, the remaining putative functional regions will be characterized, a genotyping assay will be developed to interrogate those regions deemed most likely to house a causal mutation and a new association analysis will be performed with the data from the genotyping assay, and from imputation of these regions made possible from the whole genome sequences of the beef and dairy cattle.

The BRD project was paused over the last year due to covid-19 personnel issues at the dairy where samples were being collected in Wisconsin. A new location for sample collection was required. The new site (in Ohio) has been providing samples since October and the study is on target for sample completion of 1000 calves by the end of 2022. A PhD student and three undergraduates have assisted in this project this year. Although results are being compiled for diagnostics, genomic analyses will not begin until all 1000 calves have been sampled, and results will then be presented as appropriate. Activities for this project over the next year will include completion of sampling, analysis of bacterial and viral pathogens associated with cases and controls and comparisons of the prevalence of these pathogens with calves studied in other geographic regions in the US. Genotyping of all calves will be initiated and initial quality control will be performed once the genotypes are available for analysis.

During the next reporting period we will deepen our examination of the role of the immune system in the RFI trait and relate the genomics data to gene expression data already collected. Additionally, we will characterize the chemical transformations and variation observed in vermiculture beds to determine the actual footprint of the system.

Grant funding has been obtained to do a more complete characterization of the GHG emissions, nutrient transformations and carbon trading opportunities for dairies with vermiculture. Additional grants will be submitted to examine technologies to enhance the environmental sustainability of livestock systems.

Kestrel nest boxes will be observed for occupancy rates and the efficacy of the laser deterrence methods will be tested over the next reporting period. We will also begin a new study that categorizes human-cattle interactions by their risk potential for injuries. These results will be incorporated into dairy cattle handling safety training modules.

Publications:

1. J.N. Kiser, H.L. Neibergs. 2021. Identifying loci associated with bovine corona virus in dairy and beef cattle. Frontiers in Veterinary Science - Veterinary Infectious Diseases. https://doi.org/10.3389/fvets.2021.679074

2. R.H. Nissly, N. Zaman, P.A.S. Ibrahim, K. McDaniel, L. Lim, J.N. Kiser, I. Bird, S.K. Chothe, G.L. Bhushan, K. Vandegrift, H.L. Neibergs, S.V. Kuchipudi. 2020. Influenza C and D viral load in cattle correlates with bovine respiratory disease (BRD): Emerging role of orthomyxoviruses in the pathogenesis of BRD. Virology 551(December) 10 https://doi.org/10.1016/j.virol.2020.08.014

3. J.M. Galliou, J.N. Kiser, K.F. Oliver, C.M. Seabury, J.G.N. Moraes, J. Dalton, G.W. Bums, T.E. Spencer,

4. Johnson, K. A. (2021). *Charting a Course to Sustainability* (4th ed., vol. 11, pp. 3-4). ASAS

5. Hudson, T.D., M.C. Reeves, S.A. Hall, G.G., Yorgey, **J.S. Neibergs.** 2020. Big Landscapes Meet Big Data: Informing Grazing Management in a Variable and Changing World. Rangelands, https://doi.org/10.1016/j.rala.2020.10.006.

Abstracts:

1. J.C. Dalton, J.N. Kiser, E.M. Keuter, C.M. Seabury, M. Neupane, J.G.N. Moraes, G.W. Bums, T.E. Spencer, H.L. Neibergs. 2021. Genomic markers of fertility in Holstein heifers. American Dairy Science Association meeting. Louisville, Kentucky

2. Johnson, K. A. 2021. From phlogiston to chromatin structure: The deepening of our understanding of animal energy use. ASAS, Louisville, KY, United States of America. (July 2021).

Proceedings:

1. J.C. Dalton, J. Kiser, H.L. Neibergs, T. Spencer. 2021 Genomics provides clues to dairy cattle fertility. Proceedings Western Dairy Management Conference, Reno, NV.

2. Hall, S., T. Hudson, G. Yorgey, **J.S. Neibergs,** and M. Reeves, 2020. Building Rangeland Resilience Through Engagement - Brenda and Tony Richards, Increasing resilience among ranchers in the Pacific Northwest Series, PNW737

Specialty Crops and Food Systems: Exploring Markets, Supply Chains and Policy Dimensions

Project Director

Rosa Karina Llanos

Organization

Washington State University

Accession Number

1025788

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

Fruit and vegetable growers seeking to develop sustainable and profitable markets for their specialty crops must recognize and harness opportunities emerging from changes in consumer preferences and an increasingly complex food distribution system. Despite the increased popularity of fresh produce in the U.S., and the potential for enhanced marketing revenues for producers, the majority of fresh produce continues to be marketed through large-scale wholesale and retail partners who are concerned about the efficiencies associated with scaling-up. Fundamentally, little is known about the response of increasingly demanding consumers and food supply chain partners, the changing coordination and supply chain responses of fruit and vegetable enterprises, or the response to regulations and policies developed to oversee and guide new innovations in this sector.

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.

New methodologies to improve consumers' food choice decision modeling through the labels were developed, including subjective beliefs and preferences that enable more effective simulation of the effect of promotional and informational campaigns altering consumers' beliefs. Methodologies to assess willingness to pay for different aspects of ready meals, emphasizing the convenience and nutrition aspects were developed. Access to healthy food was assessed using innovative computational methods, such as machine learning.

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

The enterprise budgets provide insights on the investment, fixed, and variable costs for establishing, producing, and packing apples and pears in Washington State, as of 2020. These studies are available free of cost to all public. Different studies on acceptance of new food processing technologies provide useful information on the food aspects that could trigger acceptance of these technologies, for example, enhanced shelf-life, organic, and clean labels. Energy costs are contributing to rising costs of production of specialty crops, lower profitability for producers and higher costs for consumers. Working on research to better understand energy costs and how to make energy markets more efficient and flexible is of increasing importance to better understanding food prices and producer profits (especially in many specialty crops) and how to make specialty crops more competitive. There are also growing issues concerning carbon emissions and how they might be reduced that the research on energy is addressing.

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

The potential long-term impacts consist of assessing those factors that could impact the acceptance of new food processing technologies, considering especially vegetables, that are prone to lose their organoleptic and nutrition qualities when processed. Other aspects such as improvements in convenience and health aspects of foods trigger the acceptance of new food processing technologies.

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.

Manoj Karkee
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Accession Number
1022721

Advancement in Automated and Precision Technologies

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

The primary focus of the proposed project is to develop mechanized and automated precision management solutions for specialty crops production, including fruit harvesting, fruit tree training and pruning, pest detection and control, and improvement of food quality and safety. Specific objectives of this project are to develop: (1) mechanized and robotic solutions (e.g., harvesting, tree pruning machines) for production of a wide range of specialty crops; (2) automated and precision solutions for biotic and abiotic stressors monitoring, and management in specialty crop production; (3) core technologies for computer-aided worksite management for practicing smart agriculture production, from data collection and analysis to decision-support system; and (4) effective methods for demonstrating and delivering the research outcomes to the 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.

Specialty crop industries in the State of Washington are facing growing global market pressures, which threaten their long-term viability. Demand for high product quality and safety, compliance with environmental protection regulations and laws, threats from invasive insects and diseases, rapidly changing climate patterns in the region, and rising energy and labor costs only amplify the challenges. Another critical challenge in specialty crop production is that field operations are highly labor intensive. The industries need technology innovations, which can assist them in maintaining a competitive position in the global marketplace by addressing these challenges. Operating from a position of high labor cost (& sacristy) and more rigorous regulations, the industry needs to adopt mechanical and/or automated approaches to solve production system problems. This project focuses on developing fundamental and applied technologies for intelligent agricultural machinery for mechanized, automated, and/or precision specialty crop productions. Some example research activities along these topic areas include robotic apple harvesting, robotic fruit tree pruning and thinning, automated green shoot thinning, precision crop water use and stress monitoring as well as intelligent (fixed and movable) chemical application technologies. The goal of this research is to provide the U.S. specialty crop producers a practical means for performing more effective and efficient field operations, with less dependence on semi-skilled seasonal human labor, and in a more environmentally friendly manner. Advancement in automated and precision technologies made through the afore-mentioned project activities is expected to help producers realize their goals on increased productivity, product quality, and profitability.

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

Scientists, specialty crop producers, agricultural equipment manufacturers technology providers, crop consultants, grower, as well as farm managers who are seeking new solutions to improve specialty crop production and efficiency are the target audience of this project. Because of the user-centered nature of this project, the end-users of developed technologies, as well as fellow researchers and general public in Pacific Northwest (PNW) region, are included in our research outcome disseminating efforts. Our project activities are leading to more robust, reliable, and affordable automated systems and precision crop stress monitoring and management techniques for specialty crops operations, some of which are being commercialized and other are getting ready for commercialization. These technologies, when adopted in commercial specialty crop production, will benefit above mentioned and help specialty crop industry to remain competitive and profitable.

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

The direct outcomes from this project were automated precise technologies for mechanized specialty crop production, which ultimately supports U.S. specialty crop producers achieve increased productivity, better product quality, and higher profitability. Project also creates resilient rural economics driven by automated/precision farming that needs skilled workforce with better paying jobs and help improve public health by consumption of locally grown produce. Overall, our project activities could help to achieve the goal of supplying the. broader public with more, better, and affordable produces.

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.

Books

1. He, Y., P. Nie, Q. Zhang and F. Liu, 2021. *Agricultural Internet of Things: Technologies and Applications*. Springer, ISBN: 978-3-030-65701-7, (439 pp).

2. Huang, Y. and Q. Zhang, 2021. *Agricultural Cybernetics*. Springer, ISBN: 978-3-030-72102-2, (255 pp).

3. Karkee, M. and Q. Zhang, 2021. *Fundamentals of Agricultural and Field Robotics*. Springer, ISBN: 978- 3-030-70399-8, (455 pp).

Book Chapters

1. He, Y, Q. Zhang, J. Zhang, and Y. Shi, 2021. Chapter 6. Field Condition Sensing Technology. In: He, Y., P. Nie, Q. Zhang, & F. Liu (eds.). *Agricultural Internet of Things, Technologies and Applications*. Springer (28 pp).

2. Karkee, M., B. Santosh, and Q. Zhang, 2021. Chapter 3. 30 Sensing Techniques and Systems. In: Karkee, M. & Q. Zhang (eds.). *Fundamentals of Agricultural and Field Robotics*. Springer (39 pp).

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5. Nie, P., Q. Zhang, and Y. He, 2021. Chapter 10. loT Management of Field Crops and Orchards. In: He, Y., P. Nie, Q. Zhang, & F. Liu (eds.). *Agricultural Internet of Things, Technologies and Applications*. Springer (12 pp).

6. Rovira-Mas, F., Q. Zhang, and V. Saiz-Rubio,. 2020. Chapter 11. Mechatronics and Intelligent Systems in Agricultural Machinery. In: Holden, **N. M.,** Wolfe, M. L., Ogejo, J. A., & Cummins, E. J. (Ed.), Introduction to Biosystems Engineering. Virginia Tech Publishing (26 pp).

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8. Zhang, Q. and**M.** Karkee, 2021. Chapter 1. Agricultural Robotics: An Introduction. In: Karkee, **M.** & Q. Zhang (eds.). *Fundamentals of Agricultural and Field Robotics*. Springer (10 pp).

9. Zhang, Q., Y. He, P. Nie, and S. Xiao, 2021. Chapter 3. Data Communication and Networking Technologies. In: He, Y., P. Nie, Q. Zhang, & F. Liu (eds.). *Agricultural Internet of Things, Technologies and Applications*. Springer (56 pp).

10. Zhang, X., Q. Zhang, M. Karkee, and M.D. Whiting, 2021. Chapter 16. Machinery-Canopy Interactions in Tree Fruit Crops. In: Karkee, **M.** & Q. Zhang (eds.). *Fundamentals of Agricultural and Field Robotics*. Springer (28 pp).

Journal Articles

1. Arai, R., S. Sakai, A. Tatsuoka, and Q. Zhang, 2021. Analytical, experimental, and numerical investigation of energy in hydraulic cylinder dynamics of agriculture scale excavators. *Energies, Accepted, 14, 621*o. https://doi.org/10.3390/en101oboo

2. Chandel, A. K., B. Molaei, L. R. Khot, R. T. Peters, C. 0. Stockle, and P. W. Jacoby. 2021. High resolution spatiotemporal water use mapping of surface and direct-root-zone drip irrigated grapevines using UAS-based thermal and multispectral remote sensing. *Remote Sensing, 13, 954*. https://doi.org/10.3390/rs13050954

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8. Kothawade, G., A. K. Chandel, L. R. Khat, S. Sankaran, A. A. Bates, and B. Schroeder. 2021. Field asymmetric ion mobility spectrometry for pre-symptomatic rot detection in stored Ranger Russet and Russet Burbank potatoes. Postharvest Biology and Technology, 181, 111679 https://doi.orq/10.1016/j.postharvbio.2021.111679

9. Lohan, S.K., Narang, M. K., Singh, M., Singh, D., Sidhu, H. S., Singh, S., Dixit, A.K, & Karkee, M. (2021). Design and development of remote-control system for two-wheel paddy transplanter. *Journal of Field Robotics*. https://doi.org/10.1002/rob.22045

10. Lohan, S. K., Narang, M. K., Singh, M., Khadatkar, A., & Karkee, **M.** (2021). Actuating force required for operating various controls of walk-behind type paddy transplanter leading to development of remotely operated system. *Journal of Agricultural Safety and Health,* 0.

11. Majeed, Y., M. Karkee, Q. Zhang, L. Fu, and M.D. Whiting, 2021. Development and performance evaluation of a machine vision system and an integrated prototype for automated green shoot thinning in vineyards. *Journal of Field Robotics,* 38: 898-916. https://doi.orq/10.1002/rob.22013

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15. Ranjan, R.; R. Sinha, L.R. Khot, G.-A. Hoheisel, **M.** Grieshop, and M. Ledebuhr. 2021. Spatial distribution of spray from a solid set canopy delivery system in a high-density apple orchard retrofitted with modified emitters. *Applied Sciences, 11, 709*. httos://doi.org/10.3390/aoo11020709

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Individual, family, and community factors associated with resilience in diverse, rural, low-income families

Project Director

Y Sano

Organization

Washington State University

Accession Number

1021344

Collecting and Analyzing interview data from Community Key Informants

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

While rural communities demonstrate strong resilience time after time, they also face unique challenges including population decline, lower labor participation rates, and demographic shifts. This project identifies factors which prevent and/or promote family resilience. Specifically, we focus on examining 1) community capacity to support resilience in diverse rural low-income families, and 2) individuals and family resilience processes from the perspective of rural, low-income mothers.

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 Washington team engaged in following major activities:

- Identified Community Key Informants from family and food security serving organizations, schools, health care and Extension in 2 Counties: Grant and Klickitat Counties.
- Based on the information above, team of interviewers at Kansas State University interviewed Community Key Informants via phone.
- An active Webinar Planning Committee developed the strategy for translating 20+ years of research findings from the project into training/discussion opportunities for family professionals across the country. Two successful webinars were held in 2020-21 with additional quarterly offerings in development. Among the 2 webinars, Washington PD made presentation and discussed how to create effective health messages targeting rural, low-income families.
- Regularly scheduled subgroup meetings for article/presentation/grant authorship
- Graduate and undergraduate students were trained in literature review and presentation skills as well as analysis of qualitative/quantitative data.
- Team members have been actively engaged in research-based outreach activities preparing family professionals to support resilience in low-income rural families in their community contexts,
- Actively participated bi-monthly full membership meetings to provide team members to share updates and discuss Community Key Informant data collection.

Progress toward the goals

Despite Covid-19 restrictions during the 2020-21 project year, we made solid progress fulfilling the project's objectives. Research and outreach activities mined secondary data from community datasets and previously collected project data .A strategy and protocol were developed to collect Community Key Informant data virtually from community key informants. We

have identified some nascent themes which emerged from our Community Key Informant (CKI) interviews. They indicate that technology is extremely beneficial to family serving organizations and that they have relied on social media and text messages to stay connected and serve low-income rural families. Communities have found innovative ways to make broadband work; however, some areas still have significant barriers regarding internet access/cell towers for community members living in rural areas outside of town. Connecting people to food resources is prominent with schools serving as a key source of food security for families. During the pandemic, pre-existing partnerships with family serving organizations have been strengthened out of necessity to cope with increased demand and new partnerships have developed within communities to leverage limited resources.

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

This project adds to the understanding of the experience and expression of resilience of families living in rural poverty. The proposed collecting of unique quantitative and qualitative datasets will capture family characteristics as well as the resources available to them through their communities. The knowledge generated from this project has direct implications for informing family-focused and community level programs intended to foster resilience.

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

We communicate our findings through peer-reviewed publications, book chapters, conference presentations, webinars, and other outreach activities. The broader public benefitted from our research because of:

- Improved knowledge of community-level assets and challenges: We have developed community profiles. In combination with the qualitative data, we are in good shape to move this impact forward in 2021-22.

- Improved understanding of factors and processes of resilience at the family level.

- Informed Extension and mobilizing community capacity; our webinars and the corresponding handouts speak to this one; the synergy that has been engaged from the project as a whole has informed research projects that help 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.

Journal Publications

1. Sano, Y., Greder, K., & Mammen, S. (2021). Development of food security messages with rural, low-income mothers. Special Issue on Rural Low-Income Families (Berry, A. and Greder, K., Eds.), *Forum on Family and Consumer Issues*, 23(1). Online journal. First made available March 2021.

2. Sano, Y., & Mammen, S. (In Press). Mitigating the impact of the Coronavirus pandemic on rural low-income families. *Journal of Family and Economic Issues*.

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1. Fenton, M.S., Radunovich, H.L., Ontai, L., & Sano, Y. (Under Review). Does a co-parent relationship serve as a protective factor against maternal depressive symptoms for rural, low- income children? *Journal of Child and Family Studies*.

2. Sano, Y., Berry, A., & Sneed, C. T. (R&R). Extension's role in addressing child, youth, and family well-being in rural communities. In M. R. de Guzmn, & H. Hatton-Bowers (Eds.) *The role of the social sciences in Extension*. New York, NY: Cambridge University Press.

3. Sano, Y., Greder, K., Mammen, S., Bao, J., & *Big Eagle, T. (Under Review). Health understanding and health outcomes among rural, low-income mothers. Submitted to *Family and Community Health*.

Publications in preparation

1. Cancel-Tirado, D. I., Feeney, S. L., Greder, K., & Sano, Y. (in preparation) Enablers and barriers to health: Comparing White and Latino rural low-income families. *Family Relations*.

2. Cancel-Tirado, D. I., Feeney, S. L., Washburn, I., Greder, K., & Sano, Y. (in preparation) Family and community-level predictors of health and well-being among Latino and white low-income families in rural areas. *Social Science and Medicine*.

3. Sano, Y., Ward, C., Houghten, M., Dyk, P. H., & Radunovich, H. (in preparation). Navigating health care challenges in rural communities.

4. Yancura, L., Ontai, L., Roth, B., Cancel-Tirado, D., & Sano, Y. (in preparation) Multigenerational Household Structure in Rural Areas: Does Grandparent Co-Residence Contribute to Overweight and Obesity?

Sustainable Solutions to Problems Affecting Bee Health

Project Director
Walter Sheppard
Organization
Washington State University
Accession Number
1021345

Honey bee germplasm and fungal-based colony health applications

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

In the US, annual colony losses over the past 10 years have ranged between 35%-45%. The collaborative multi-state NC1173 strives to evaluate the role, causative mechanisms, and interaction effects of biotic (i.e. parasitic mites, pests, and pathogens) and abiotic stressors (i.e. exposure to pesticides, poor habitat and nutrition, management practices) on the survival, health and productivity of honey bee colonies and other species within pollinator communities. A strong association between the parasitic mite *Varroa destructor*, deformed wing virus (DWV), and high overwintering colony losses of honey bees is well-established.

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 WSU bee team has been breeding a novel strain of Metarhizium fungus for improvement as a biological control agent against *Varroa* mites. In 2021, the team conducted outdoor studies comparing Metarhizium to oxalic acid, a commonly utilized mite treatment, and showed that the Metarhizum exhibited comparable mite control. Additional testing (i.e., nutritional analysis) of polypore mushroom extracts for potential use as a honey bee feed additive were carried out and indicated that the extracts have a mineral composition similar to honey and pollen and an AAFCO (The Association of American Feed Control Officials) requested longevity study was completed. WSU has coordinated with AAFCO and the FDA to seek a smooth and quick route to registration as a honey bee feed additive.

The WSU bee team continued selection and maintenance of the New World Carniolan strain of honey bee in 2021, including inputs of cryopreserved *A. m. carnica* germplasm from Slovenia origin. Together with industry partners, WSU implemented the hand-off the production of New World Carniolan instrumentally inseminated breeder queens to commercial queen producers in 2021. WSU remains responsible for maintenance of the genetic stocks and infusion of *A. m. carnica* genetics from our repository of cryopreserved Old-World semen. In addition, WSU continued selection and distribution of a Caucasian strain

of honey bees derived from Old-World origins. In 2021 we supplied i.i. breeder queens to a number of commercial queen producers, who produced open-mated daughters for sale throughout the US. This strain is especially interesting to beekeepers from colder climates within the US.

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

WSU bee team activities in project NC1173 in 2021 primarily benefitted our target audience through the availability of novel genetic material from various commercial sources that rely on WSU sourced germplasm via breeder queens. This includes the New World Carniolan strain of honey bees supplied by several large queen producers in the US, including those in California and Hawaii. WSU selects, maintains and produces the instrumentally inseminated queens that are supplied to large scale queen producers who then produce tens of thousands of daughter "production" queens that are sold to beekeepers across the US. In 2021 the WSU bee program also supplied instrumentally inseminated breeder queens derived from the cold-weather adapted bee, *Apis mellifera caucasica,* using germplasm collected in the Caucasus Mountains of Georgia. This is part of an effort to reintroduce this strain of honey bees to the US to provide beekeepers additional genetic diversity within US honey bee populations.

In 2021, the WSU bee program made significant progress toward getting AAFCO (and FDA) approval for a fungal-based feed additive. This additive will help assist beekeepers in maintaining healthy colonies and we hope for full approval in 2022. Our 2021 progress in field testing a selected fungus with biocontrol potential (Metaryzium) will be used as a basis for a large-scale field evaluation in 2022 and submission of a preliminary patent, as steps toward future realization of a usable product for beekeepers .

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

The broader public relies on a robust and healthy pollinating force for agricultural crops to maintain food security. Our work in providing improved genetic stocks of honey bees to beekeepers in 2021 contributed to the overall health and reliability of the pollinating force available to growers and orchardists. The existence of a strong pollinating force is critical to continued agricultural reliability for food production, especially at the present time, when the average annual losses of colonies remains over 35%. WSU bee program contributions to the larger project (NC1173) including honey bee genetics, fungal based products both to control parasitic mites and as a feeding additive, indoor wintering and other management research reflects our continuing emphasis on improving honey bee colony healthe

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.

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4) Sheppard, W.S. 2021. Honey Bee Pests *in* Pacific Northwest Insect Management Handbook. c8-c10.

Integrated Crop and Weed Management Systems

Project Director
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Accession Number
1017286

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

The goal of this program is to develop and apply innovative and contemporary tools of crop science to address the challenges and opportunities facing the agricultural industry of Washington. Program scientists have studied the morphological, physiological, crop yield and crop quality responses of critical regional crops including cereal, small fruit, and vegetable crops, to management practices such as grafting, tillage, planting method, fertilization, irrigation, plant growth regulators, herbicides, and residue management.

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 activities and knowledge gained from these activities was used to refine, or develop new, production practices for crops grown in Washington, in alignment with the goals of the project.

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

The target audience benefited through improved crop production and weed management input tactics and strategies for crops of focus.

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

The broader public benefited through improved food security associated with more resilient crop management approaches for Washington crop production systems.

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.

Although COVID-19 curtailed all in-person events during the program period, on-line resources including websites, videos, extension publications, and virtual meetings disseminated information to users.

Marija Savic started her M.S. project looking at the effect of day vs. night applications of glyphosate with various surfactants. Pinki Devi completed her PhD in May 2021. Srijana Shrestha and Aidan Kendall carried out their final MS field research, Alex Cornwall initiated his PhD research, and Ann Kowenstrot began he MSAg program. Lydia Fields completed her MS degree in May 2021 with a focus on using a light activated weed sensing sprayer for managing weeds in fallow.

1. Yu, Yingxue, Deirdre E. Griffin-LaHue, Carol A. Miles, Douglas G. Hayes, and Markus Flury. 2021. Are micro- and nanoplastics from soil-biodegradable plastic mulches an environmental concern? Journal of Hazardous Materials Advances, 4: 100024. https://doi.org/10.1016/j.hazadv.2021.100024

2. Anunciado, M., L. Wadsworth, S. Ghimire, C. Miles, J. Moore, A. Wszelaki, and D. Hayes. 2021. Deterioration of soil-biodegradable mulch films during storage and its impact on specialty crop production. HortTech 31:798-809. https://doi.org/10.21273/HORTTECH04922-21

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Reducing the Impact of Pests and Diseases Affecting Washington Agriculture

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Reducing the Impact of Pests and Diseases Affecting Washington Agriculture

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

Many diseases impact a wide range of agronomic and horticultural crops grown in WA State. Therefore, management of virus impacting the quality and crop health were identified as one of the highest research priorities for sustainability of the agricultural enterprise in the state.

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.

We have documented that FRAC 11 fungicide resistance is prevalent in Washington, and growers are using our testing approaches to adjust their spray programs and improve fungicide stewardship. We have shown that preplant fumigation in vineyards is not a long-term solution for nematode management. Our trials have provided a rating metric on nematode resistant vs. tolerant rootstocks, and we now know how these rootstocks perform long-term under field conditions. We have identified different species of fungal pathogens associated with grapevine trunk diseases in Washington, and have evaluated dormant spray treatments to provide growers a mechanism to reduce pruning wound infections.

Field studies have shown that roguing or removing symptomatic vines was found to be less effective in managing grapevine leafroll disease due to field spread of the disease by mealybug and scale insect vectors. In contrast, roguing of symptomatic vines followed by replanting with virus-tested cuttings was shown to be an effective low-cost strategy for managing grapevine red blotch disease in vineyards. A comprehensive phylogenetic analysis of near-complete genome sequence of *Grapevine leafroll-associated virus 3* (GLRaV-3) isolates showed the presence of unusually diverse and novel genetic variants in Washington vineyards. We engineered *Grapevine leafroll-associated virus 1* (GLRaV-1) to build a minireplicon system to study viral sequences required for RNA replication. Grapevine rupestris vein feathering virus and grapevine red globe virus were reported for the first time in Washington vineyards. Studies were conducted on the epidemiology of *Tobacco ringspot virus* (TRSV) infecting highbush blueberries.

In 2021 our research described several major aspects of the little cherry virus and X-disease phytoplasma pathogen systems including a) the in-planta infection cycle and seasonality of both virus and phytoplasma, b) alternative hosts of the phytoplasma, X-disease symptom development in both cherry and peach, d) genetic diversity of both pathogens, and e) phytoplasma incidence in leafhopper vector species. Cumulatively this research represents the first systematic study of little cherry and X-disease biology and epidemiology in 40 years and will be critical in developing methods to combat the current epidemic and in the long term, developing a sustainable IPM program for cherry. We also commenced a study into the pathogenicity of the latent hop viruses to better understand their effects on hop productivity and yield.

As Berry and Potato Pathology (BPP) program was started in Feb 2021, major activities focused on developing a new research and extension program. This involved several one-on-one interactions with blueberry and potato growers and stakeholders to understand their research needs, identifying progressive growers, as well as networking with County extension agents and other researchers in the Pacific Northwest. The program also provided weekly mummy berry updates in Spring 2021 to blueberry growers. The PI worked with a seed potato grower who offered their farm, labor, and seed crop as an experimental site for on-farm collaboration. Further, disease diagnostic service was provided to two potato growers during the 2021 field season.

Thrips-transmitted Iris yellow spot virus (IYSV) continues to be constraint to onion production in WA State. An in-depth analysis of the genetic diversity of IYSV was carried out. The complete N gene sequences of 142 IYSV isolates of curated sequence data from GenBank were used to determine the genetic diversity and evolutionary pattern. In silico restriction fragment length polymorphism (RFLP) analysis, codon-based maximum likelihood studies, genetic differentiation and gene flow within the populations of IYSV genotypes were investigated. Bayesian phylogenetic analysis was carried out to estimate the evolutionary rate. In silico RFLP analysis of N gene sequences categorized IYSV isolates into two major genotypes viz., IYSV Netherlands (IYSVNL; 55.63%), IYSV Brazil (IYSVBR; 38.73%) and the rest fell in neither group [IYSV other (IYSVother; 5.63%)]. Phylogenetic tree largely corroborated the results of RFLP analysis and the IYSV genotypes clustered into IYSVNL and IYSVBR genotypes. Genetic diversity test revealed IYSVother to be more diverse than IYSVNL and IYSVBR. IYSVNL and IYSVBR genotypes are under purifying selection and population expansion, whereas IYSVother showed decreasing population size and hence appear to be under balancing selection. IYSVBR is least differentiated from IYSVother compared to IYSVNL genotype based on nucleotide diversity. Three putative recombinant events were found in the N gene of IYSV isolates based on RDP analysis.

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

Commercial wine and juice grape growers now better understanding the role fungicide resistance plays in crop loss, and how to better approach vineyard replant scenarios when faced with sites plagued with trunk diseases and plant parasitic nematodes. In particular, improved fungicide spray programs can save growers millions of dollars – improving control efficacy which generally reduces the total number of "rescue sprays" saves $1M-$2M per spray (statewide). We have also now have information on rootstock use, and value of preplant fumigation, which Washington wine grape growers are now adopting in their new vineyard plantings (i.e., adopting rootstocks, not using fumigation).

Dissemination of project results has benefited the grape and wine industry that is currently contributing an estimated $5 billion to Washington State's economy. Since managing virus diseases affecting vine health and fruit yield and quality is recognized by the grape and wine industry as one of the highest priorities, the project outputs have contributed to implementation of science-based best practice guidelines to manage viral diseases in certified nurseries and grower vineyards for long-term sustainability of the wine grape industry

Through collaborative research projects on little cherry/X-disease, growers and producers are able to focus their management efforts on key points within the pathosystem, including targeting optimal pathogen transmission times and alternate hosts to reduce pathogen load in the orchard. Similarly, our research into hop virus pathogenicity will allow growers to make informed management decisions.

Mummy berry is an important disease of blueberries in western Washington. The weekly updates provided by the BPP program aided growers to take timely decisions to manage the disease. The seed potato grower who collaborated with the PI on dormant tuber testing technology for necrotic viruses received results about their seed crop within a week after sampling compared to three to four months with conventional winter grow out testing methods. This project provided awareness among seed growers in Washington to explore newer testing methods to improve their seed potato health.

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

All of these activities are aimed at providing evidenced-based decision support tools so that grape growers can make informed pest management choices. Informed choices reduce the potential for unnecessary pesticide applications in vineyards. Together, this can reduce the negative environmental impacts associated with pest management in wine grapes. Our solutions have also provided non-chemical approaches (i.e., rootstocks, cover crops) that offer softer, sustainable, integrated pest management solutions for Washington growers, and beyond.

The broader public benefits from our research efforts by having more sustainable specialty crop production in Washington state, including Cherries and Hops, and through more focused disease management efforts, reducing pesticide inputs into the environment.

It is essential to protect blueberry crop from disease pressure so that Washington state continues to lead the nation in blueberry production. Activities conducted by the BPP program in 2021 focused on achieving this broader goal. Likewise, Washington grows the highest number of potato varieties among the fifteen seed potato growing states in the nation. BPP program activities conducted in 2021 would allow Washington seed potato growers to continue to lead the production of healthy and profitable seed potatoes of new specialty potato varieties.

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.

Refereed Journal Articles

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Enhancing Sustainability Across Diverse Agricultural Systems

Project Director

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1014754

Enhancing Sustainability Across Diverse Agricultural Systems

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

The current dominant farming systems in the U.S. are unsustainable. Soil and other natural resources continue to degrade, the number of farms continue to decline, and pesticide contamination of foods persists. Even certified organic farms are challenged to prevent pesticide contamination of their 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.

Our program uses a wide range of biophysical and sociological techniques to understand the challenges farmers face and test alternatives to current farming methods. Biophysical research including field and greenhouse trials informing researchers and farmers about the performance of new methods and materials. For instance, trials of organic herbicides in cooperator fields and orchards allow us to test the effective timing of application of the materials and compare their cost to other methods of weed management. These data allow us to support farmer decisions on using these materials to expand organic production or reduce labor costs. Online surveys, web-push surveys, and virtual focus groups are key tools we use to determine farmer research needs, consumer attitudes, and human decisions that affect farming sustainability.

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

Growers using organic and other improved sustainability methods benefit from increased knowledge about organic products, alternative crops, and effective disease control methods. For instance, presentations to growers have improved the effectiveness and cost effectiveness of their use of organic herbicides. Our outreach activities have improved profitability and environmental impacts of thousands of acres of farmland and over 100 small farm businesses.

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

By helping to expand organic acreage and improve sustainability in conventional agriculture, the broader public benefits through food quality and environmental protection. Effective management of weeds and crop diseases using more sustainable methods maintains high productivity and reduces pesticide residues on foods. Agricultural lands provide critical environmental resources such as nutrient cycling, moderating greenhouse gas fluxes, and pollinator habitat. These services are protected and enhanced through sustainable farming methods and acreage.

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.

Public presentations and workshops were provided through field days, webinars, Tilth Alliance conference, and Conservation Districts. The Cultivating Success Sustainable Small Farming and Ranching course uses statewide experts to support farmer learning and economic sustainability.

Closing Out (end date 09/07/2023)

Molecular Plant Sciences (MPS): Plant Productivity in a Dynamic Environment

Project Director
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Molecular Plant Sciences (MPS): Plant Productivity in a Dynamic Environment

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

The project focuses six research areas in two groups: A1-A3 (Products and Synthesis) and B1-B3 (Defense and Signaling). Accomplishments in these areas are summarized below.

Group A1: Primary metabolism (Kirchhoff, Okita). Plant productivity is governed by the photochemical-biochemical events leading to CO2 fixation and ATP formation as well as the efficiency of conversion of photosynthate to support vegetative growth and accumulation of storage reserves in developing sink organs. However, plants live in a complex environment with rapid changes in abiotic parameters like sunlight intensity and quality. A key mechanism that allows plants to thrive under these conditions is a dynamic response of the photosynthetic thylakoid architecture in the chloroplasts that adjusts energy converting performance to actual needs. Dr. Kirchhoff lab studies factors that control structural changes of the thylakoid membranes that are central to understanding the plasticity of the energy-converting apparatus. Unraveling these factors can pave the way for engineering crops with better performance in the changing environment. Furthermore, recent developments have indicated that in addition to its role in starch initiation and starch grain maturation, the plastidial phosphorylase, Pho1, has a second distinctive role in photosynthesis. Dr. Okita's laboratory uncovers how Pho1 and its L80 domain modulates the synthesis of reductant via photosystem I and, in turn, plant growth and development.

Group A2: Secondary metabolism (Bates, Bartley, Browse, Roje, Lewis, Gang, Lange). Laboratories of Dr. Bates and Dr Browse investigate how plants control oil biosynthesis in plant seeds and leaves. Advanced analysis of the genetics and biochemistry of lipid metabolism in oilseeds enables successful design and engineering of healthy food oils, and plant oils for bioenergy and as suitable feedstocks to industrial green chemistry.

Laboratories of Dr. Gang and Dr. Lange study secondary metabolites with particular focus on medicinal compounds. Although medicinal plants are well known to produce many compounds of importance for human health, how they produce such compounds and how those processes are controlled and regulated in the plant is not well understood. A better understanding of how medicinal compounds are generated by their producing plants will lead to improvements in crop and compound yield, production with lower inputs (energy, water, nutrients), and less environmental impact of medicinal compound production

for human health applications. Research in Dr. Gang's laboratory has shifted emphasis to hemp in recent years due to its great potential as both a medicinal compound producer, as well as its utility for bioenergy, bioproducts and biomaterials generation. Dr. Lange

laboratory develops, maintains, and expands web-based resources for research on plant natural products.

Dr. Lewis' laboratory collaborates with Pan Pacific personnel, as part of our PACE (Producing Algae for Coproducts and Energy) consortium, to address the deployment of algae as a source of biomass that can be converted to biofuel and co-products economically. This required development and improved process engineering to target an energy return on investment (EROI≥ 3), a C index of≤ 55 grams CO2 per megajoule, and a *circa* 2-fold reduction in fuel cost (to≤ $5 per gallon of gasoline equivalent (gge).

Dr. Bartley's laboratory seeks to identify and alter the expression of genes that grasses use to synthesize their cell walls. The aim is to improve lignocellulosic biomass composition to increase the efficiency of biomass use for production of biofuels or other chemicals. In addition, for maintaining and increasing biomass yields, it is important to understand how cell wall alteration alterations influence plant growth and physiology.

Dr. Roje's lab studies biosynthesis of flavins and regulation of the flavin biosynthetic pathway in plants. Flavins are essential cofactors for many enzymes, and constitute the nutritional source of vitamin B2 in plants. Our goal is to understand the pathway and its regulation so that we can use this knowledge to produce crops with improved nutritional value.

Group A3: Roots / Products and Synthesis (Sanguinet, Kahn).

Dr. Kahn's laboratory works on Increasing the production of fixed nitrogen by improving the various interactions between symbiotic rhizobia and legumes could make a significant contribution to world food production. Understanding the metabolic exchanges operating in these interactions is likely to be key to any increase.

Dr. Sanguinet's laboratory studies root development and functional genetics and genomics in crop and model plants. A significant emphasis is also on abiotic stresses including cold and drought in wheat and *Brachypodium distachyon* as well as climate resilience in the alternative oilseed pennycress, *Thlaspi arvense*.

Group B1: Signals and Hormones (Poovaiah, Tanaka, Neff).

Dr. Neff's laboratory studies how external signals (primarily light and temperature) interact with internal cues such as hormone pathways to regulate plant growth and development. The research involves fundamental research using model systems, such as *Arabidopsis thaliana* (dicot/brassica) and *Brachypodium distachyon* (monocot/cool season-grass) for genetic discovery while translating this information into applications in crop plants. Some current projects include understanding the role of brassinosteroids and DNA-binding proteins in seed/seedling development, the role of winter in survivability in the brassica canola and flowering time in the cool-season grass Kentucky bluegrass, and breeding grasses for turf applications, land reclamation, drought tolerance and climate change.

controls the synthesis of reductant via photosystem I and, in turn, plant growth and development.

Dr. Poovaiah's laboratory studies how Calcium (Ca^{2+}) signaling regulates salicylic acid (SA)-mediated immune response through calmodulin-meditated transcriptional activators, AtSRs/CAMTAs. We have reported an AtSR1/CAMTA3-mediated regulatory mechanism involving the expression of the SA receptor, NPR1. Our results revealed a role for AtSR1 as a Ca^{2+}-mediated transcription regulator in controlling the NPR1-mediated plant immune response.

Dr. Tanaka's laboratory works on signaling mechanisms of plant-pathogen interactions. Plants sense self damage by recognizing release of damage-associated molecules when they get attacked by herbivores and pathogens. The main research focus is understanding how plants induce a variety of defense responses based on the damage-associated immune system. We also attempt to use this immune system for plant protections for potatoes and other crops.

Group B2: Stress Response (Smertenko, Gill).

Dr. Smertenko's laboratory works on mechanisms of plant resiliency to heat and drought stress. Both stress factors pose a threat to the state economy. For example, USDA National Agricultural Statistics Service estimated overall losses to the Washington State wheat industry from these stresses in 2015 alone to be $199.5 million.

The project in Dr. Gill's laboratory focuses on understanding mechanisms by which the homoeologous chromosomes are distinguished from homologs and non-homologs among polyploids. In addition to understanding this basic biological process, the project outcomes also have potential application in alien gene transfer.

Group B3: Roots / Defense and Signaling (Peters, Gleason)

Dr. Gleason's laboratory works on root pathogens, nematodes. Root-knot nematodes (*Meloidogyne* spp) are serious pathogens of several high value crop plants, including potato. Due to the lack of natural genetic resistance in most plants, growers control root-knot nematodes by applying synthetic chemical nematicides, which are dangerous to human health and the environment. The Columbia root-knot nematode (CRKN) is the biggest nematode problem for potato growers in the Pacific Northwest, but there is very little molecular information about this nematode. This project addresses the need for obtaining molecular and genetic information about the CRKN and developing new tools for nematode control in potato and other crops.

Dr. Peters' project aims at engineering ammonium-excreting bacterial strains using *Azotobacter vinelandii*. The strains generated can provide promising biofertilizers for use in agriculture to promote the growth of plants under fixed nitrogen-limiting 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.

Activities and significant progress towards the goals in each project area are summarized below.

Group A1: Primary metabolism (Kirchhoff, Okita).

Dr. Kirchhoff's laboratory discovered how cations interact with the photosynthetic thylakoid membranes to control the stacking of the membranes to grana as well as the membrane energization and photoprotective non-photochemical quenching process. In another project we unraveled that the ontogenetic status of a resurrection plant that can survive desiccation over long time periods determines whether a more degradation-based or a more photoprotective mechanism is employed during dehydration. These studies help to understand how the structural flexibility of thylakoid membranes adjusts the photosynthetic efficiency in plants to changing environmental conditions.

Dr. Okita's laboratory identifies what proteins of ~~the~~ photosystem I interact with Pho1. It was demonstrated using two different independent methods that Pho1 interacts with two proteins of photosystem I.

Group A2: Secondary metabolism (Bates, Bartley, Browse, Roje, Lewis, Gang, Lange).

Dr. Bates lab performed isotopic tracing of *Physaria fendleri* seed lipid biosynthesis and discovered that *P. fendleri* utilizes a novel triacylglycerol remodeling pathway to accumulate industrially valuable fatty acids in seed oils. Ongoing research is elucidating the genes which control triacylglycerol remodeling.

Dr. Browse's laboratory demonstrated that hydroxy fatty acids accumulating seeds are unable to rapidly mobilize hydroxy fatty acids containing triacylglycerol (TAG) storage lipid after germination to provide carbon and energy for seedling development, resulting in reduced seedling establishment. These findings present a new opportunity to investigate a different, key area of lipid metabolism - the pathways of TAG lipolysis and beta-oxidation in germinating seedlings.

Dr. Gang's laboratory participated in national variety trials for hemp and other significant hemp-related research efforts. Due to significant weather events, major issues related to hemp growth under diverse environments were brought to the forefront of our research efforts. We also were part of successful competitive proposal efforts, leading to new funding from NIFA for our hemp research efforts.

Dr. Lange's laboratory continued to expand the NMR spectral coverage of natural products in the Spektraris database. We have also supported the research community with the structural identification of metabolites with roles in plant fitness and human nutrition.

Dr. Bartley laboratory contributed to the completion of the genome of switchgrass and cataloging of switchgrass diversity. In addition, we have found that there is a lag between expression of genes that alter biomass composition and the actuation of a change in biomass composition. Since one of the tools for understanding and controlling gene function is to use genome editing, we have established an inexpensive and rapid method to use a third-generation sequencing technology (Oxford Nanopore) to identify genetically edited plant lines.

Dr. Lewis' laboratory deployed genetic engineering of algae to produce phenyl ethanol (glucoside), PEA (GlC), an EROI ? 2.9), a C index of? 59.95 grams CO2/MJ, and a *circa* 2-fold reduction in fuel cost (to= $4.79 per gge was achieved in our current process engineering design model. Without the co-products offset, biofuel cost would be *ca* $6.81per gge.

Dr. Roje's laboratory produced transgenic plants with modified levels of flavin biosynthesis genes. Using transcriptional profiling of these plants, we have identified a set of candidate genes that may be involved in regulation of flavin biosynthesis, and are spearheading the study of those genes.

Group A3: Roots / Products and Synthesis (Sanguinet, Kahn).

Dr. Kahn's laboratory cataloged bacterial and plant proteins expressed in the nitrogen fixing root nodules and, in one instance, used the information to discover new genes that affect symbiotic productivity. We have also authored a hypothesis explaining the relationships between nutrient stress conditions in the bacteria.

Dr. Sanguinet's laboratory made progress in understanding how the BUZZ CDK functions in root developmental plasticity and nitrogen responses in *Brachypodium distachyon, Arabidopsis thaliana* and maize. We also used RNAscope to localize the *BUZZ* transcript at root tips. In addition, developed a freeze tolerance test protocol for pennycress.

Group B1: Signals and Hormones (Poovaiah, Tanaka, Neff).

One of the major activities in Dr. Neff's laboratory relates to how winter regulates flowering the following summer in Kentucky bluegrass. This process is known as vernalization. Warm winters lead to lower seed yields the following year. We have been identifying and characterizing the genes involved in vernalization. We have also been using fall applications of the plant hormone, gibberellin, as a stimulator of flowering in Kentucky bluegrass. We have also been breeding new varieties of Kentucky bluegrass that have a reduced vernalization requirement for flowering and seed production.

Research in Dr. Poovaiah's laboratory indicated that calcium/calmodulin-mediated signaling plays a critical role in controlling plant immunity.

Dr. Tanaka laboratory studied cytosolic calcium signaling in plant immune response. We found that ROS (another second messenger) was required for tuning, but not for initiation of calcium signaling, while calcium was required for both initiation and tuning of ROS signaling, providing a clearer picture of how ROS and calcium signatures are required for proper dynamics for plant defense. Matthew Marcec (MPS Ph.D. student) presented a poster at the Plant Biology Worldwide Summit. His manuscript was just published this year (Marcec and Tanaka, 2022). Improving disease control strategies are important for crop protection and safeguarding human health and the environment by reducing the use of harmful chemicals. We have focused on a soilborne potato disease, potato powdery scab disease, which has in recent decades insidiously spread in many regions where potatoes are grown, including most potato production areas in Washington State. We also focus on a potato disease so-called Silver scurf, which is an important postharvest disease that causes blemishes and lesions with characteristic silvery patches on tuber skins. The cosmetic damage negatively affects the processing and fresh market. Recent contributions in these studies of the fields were by developing new diagnostics and by screening of new types of pesticides based on natural compounds, some of which are known for priming and inducing plant immunity (= elicitation). These researches are significant to develop integrated disease management in the future.

Group B2: Stress Response (Smertenko, Gill).

Dr. Smertenko's laboratory developed makers of autophagy under drought stress. We identified autophagic genes that are up-regulated under drought stress in published RNA-Seq datasets of rice, maize, and sorghum. This information was used to develop antibodies against two autophagy markers and demonstrated usability of these markers for measuring activity of autophagy under drought stress. We also developed antibodies against catalase and measured changes of catalase level in response to drought stress. Another direction of our work focused on holistic analysis of formins functions in plant cell division. We demonstrated that formins in addition to regulating actin filaments, also control microtubule dynamics and membrane fusion.

Dr. Gill's laboratory has shown that gene, C-Ph1, can be manipulated to transfer genes from wild relatives into crop plants.

Group B3: Roots / Defense and Signaling (Peters, Gleason).

Dr. Gleason's laboratory and collaborators sequenced the genome of the CRKN. They also looked at genes expressed during nematode infections of potatoes. Altogether, the data they generated provided new information about nematode parasitism and the mechanisms by which the nematodes are manipulating plants to their own benefit.

Dr. Peters's laboratory worked on defining discrete determinants that bring about *Azotobacter vinelandii* ammonium excretion and demonstrates that strains can be generated through simple gene editing to provide promising biofertilizers capable of transferring nitrogen to crops.

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

The project resulted in 57 published papers in peer-reviewed journals, one manuscript is in press, and one manuscript submitted. Three PhD theses were published. Results were presented at 15 scientific seminars, 8 presentations at conferences and workshops, three presentation at the commodity groups: one at Spokane Ag Show/Pacific Northwest Farm Forum 2021 and two at Washington Grain Commission, one article was published in Oregon Mint Commission Spring Newsletter. Further benefits to researches, industry, stakeholders, and general public are described below.

Group A1: Primary metabolism (Kirchhoff, Okita). Discovery on the drought response in resurrection plants that helps to understand how plants react to water stress informs on new approaches for improving drought resiliency in plants. Researchers studying membrane biology will find our results on cation-thylakoid membrane interactions beneficial since the fine balance of physicochemical forces around biological membranes is still not well understood. Scientists who are pursuing studies to genetically improve crop plants via manipulation of source-sink relationships and basic research scientists interested in understanding the mechanisms responsible for starch synthesis and accumulation will benefit from our discoveries.

Group A2: Secondary metabolism (Bates, Bartley, Browse, Roje, Lewis, Gang, Lange). Sequencing of the switchgrass genome permits understanding of the gene complement of this biofuel crop and rationale and breeding approaches to improvement of this bioenergy crop. Understanding the lag between gene expression and lignocellulosic development pinpoints the time when researchers can study and identify additional genes that function in control of biomass composition and thereby improve straw quality for plants, such as wheat, for use in lignoncellulosic fuel production.

The third-generation sequencing technology approach to identify edited plants can be used by other project members and the research community at large to accelerate their genome editing experiments.

Successful efforts to increase the accumulation of industrially useful hydroxy fatty acids in transgenic plants have led to important new discoveries about the pathways and regulation of plant lipid synthesis more broadly. Our current results indicate a new metabolic pathway that could be manipulated for optimizing plant oil fatty acid compositions. Improved knowledge of flavin biosynthesis and regulation brings us closer to the ultimate goal of producing more nutrient-dense crops.

A final publicly available report to DOE BETO (approximately 285 pages) has been completed by the PACE Management Team for the circa $12 million consortium project. The PACE PI (Dr. Matt Posewitz) reported the overall results on September 28, 2021 to the Algal Biomass Organization virtual meeting/symposium, including the algal genetic engineering advancements.

Group A3: Roots / Products and Synthesis (Sanguinet, Kahn). New ways to think about the symbiosis and to approach key questions, especially related to plant-microbe interactions at its heart.

Our work on the BUZZ CDK will help to understand root responses to the environment and in particular nitrogen, a major synthetic fertilizer. Also, our work in pennycress will help to understand the molecular basis of freezing tolerance in other Brassica species like canola and camelina.

Group B1: Signals and Hormones (Poovaiah, Tanaka, Neff). Roughly 90% of the Kentucky bluegrass seed used worldwide is produced by farmers in the Inland Pacific Northwest with roughly 80% produced in Washington State. Our studies on vernalization are likely to lead to new scientific information on how this process influences flowering and seed production in this perennial cool-season grass. Our studies are also likely to increase Kentucky bluegrass seed yield in the face of warmer winters caused by climate change. We also work on other native and non-native grasses which may help the general public grow lawns and gardens that require lower inputs such as water and fertilizer. This will, in turn, lead to a greater demand for new grass varieties that can also be produced in the Inland Pacific Northwest. Information about calcium signaling will enable engineering disease-resistant plants, which should benefit the stakeholders. Knowledge gained from our research would eventually help solve pressing agricultural problems that are relevant for Washington State growers as well as farmers in other states and countries worldwide. Some knowledge gained from our research is directly useful to the local commodity commissions, farmers and other stakeholders.

Group B2: Stress Response (Smertenko, Gill). Information about drought and heat tolerance mechanisms was published in research papers. Information also progressed in the field of chromosome pairing, recombination and homology search. This information will help the scientific community to understand the mechanism of these very important biological processes. The application of the information in alien gene transfer will benefit industry, stakeholders, farmers and the public at large by transferring value-added genes from wild relatives into crop plants.

Group B3: Roots / Defense and Signaling (Peters, Gleason). Research community benefited from deposited gene and transcriptome data into public databases. We have provided one of the most complete root-knot nematode genomes to date. Industry and stakeholders have benefited from this research because the project activities have helped us understand the

plant side of the plant-nematode interaction, including the plant targets of nematode gene products. This information will be useful in engineering novel nematode resistance.

Generation of ammonium-excreting derivatives in *Azotobacter vinelandii* in the absence of any transgenes through gene editing approaches using native promoter sequences allowed us to modulate and control the amount of ammonium produced. This feature is an important asset to be able (1) to match the specific fixed nitrogen requirements for each crop and cultivar targeted, (2) to control the impact of the use of these biofertilizers on the influx of ammonium into the terrestrial biogeochemical nitrogen cycle, and (3) to minimize the metabolic load and fitness cost on the organism of the expression of multiple transgenes. The ammonium-excreting strains constructed in this work have been shown to significantly stimulate the transfer of fixed nitrogen to rice plants, suggesting that these strains could be used as effective biofertilizers.

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

Two popular articles were published in the magazine Wheat Life; research outcomes of the project were featured in one publication in LabManager and in The Cannabis Scientist. One video, one web blog, two news articles by the WSU press office, and four podcasts were produced. In addition the project results will lead to the following benefits to the broader public.

1. Reduce dependence on petroleum sources for fuels and chemicals.

2. Aid in developing oil crop plants that can be used to replace petroleum products in various applications, and engineer current oilseed crops for enhanced fatty acid compositions for use in the food, chemical, and bio-fuel industries.

3. Providing chemical feedstocks from renewable plant oils is a key step to reducing fossil fuel use and securing a carbon-neutral economy to limit global warming.

4. Enable developing safer methods to control root-knot nematodes due to the foundational research in root-knot nematode genomics and transcriptomics.

5. Enable growth plants on space stations using nitrogen fixing bacteria to provide nitrogen.

6. Help improve the growth and health of crop plants and the development of biofuel prospects since photosynthesis is the central energy converting process in plants. Therefore, our research is beneficial for the area's food and energy.

7. Low-input lawns, gardens and native grasses have many benefits including environmental cooling, food production and land restoration. Our fundamental and applied research efforts are likely to help the broader public grow lawns, gardens and restore damaged land with the use of fewer inputs such as water and fertilizer.

8. Contribute to increasing the world's food supply by enhancing crop yields.

9. Engineered inoculants capable of producing ammonium in excess that promote the growth of plants under fixed nitrogen-limiting conditions. Provide important new insights for developing a blueprint for engineering microorganisms for effective biofertilizers.

10. Control immunity/plant disease resistance and developing novel crop protection strategies, which eventually will meet societal demand for reducing the environmental and human health costs of relying on synthetic pesticides.

11. On November 6 2021 twenty high school students from Native American Communities from Oregon, Washington, and Idaho States were hosted on WSU Pullman campus. Students were engaged in lab-based mini-projects that gave them hands-on experience in electrophoresis, microscopy, and chemical assays.

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.

Several PIs have experienced problems during 2021or considering changes as outlined below.

Bartley laboratory. Some of the lignocellulosic genes that we are studying are not amenable to genome editing, as we are unable to generate transgenic plants that lack these genes. We will instead be using knock-down technologies.

Neff laboratory. The biggest challenge with our current project is developing a sustainable Grass Breeding and Ecology Farm, now that it has been built and put into use. This problem is being addressed by procuring external grants to fund our breeding efforts (e.g. Washington Turfgrass Seed Commission, US Golf Association, National Turf Evaluation Program) as well as ecological studies and native and non-native plant blends used in roadside ditch plantings for stormwater management (e.g. City of Tacoma Stormwater Action Monitoring Group). We have also established a Grass Breeding and Ecology Advisory Board and are working on licensing new varieties of grasses for seed production. The long-term goal is to develop new varieties of grasses that can be awarded Plant Variety Protection (PVP) status and then licensed to grass seed producers which will then pay licensing and royalty fees to Washington State University to be used as financial support for the Grass Breeding and Ecology Farm program.

Sanguinet laboratory. The Covid-19 pandemic, supply chain issues, and maintaining the safety and well-being of my team meant that timelines and progress on data collection and research progress were significantly slowed down. It also delayed the arrival of an international postdoctoral scientist by 6 months.

Smertenko laboratory. This year we conducted field trials with spring varieties in two WSU research farms in Othello and Lind. Reduced precipitation during spring 2021 resulted in very dry soil. A strong wind blew away topsoil with fertilizer in Othello. As a consequence, the growth of plants was not uniform and it was not possible to get reliable data. High temperatures in Lind coincided with anthesis and seed development was abrogated leading to lack of statistical significance of differences between analyzed genotypes. Furthermore, plants were in a very bad physiological condition due to the high heat. As a consequence experiments at both sites have failed. This delayed our progress in identification of markers of efficient ROS homeostasis.

The project PI, Michael Kahn, will probably retire from WSU in 2022 but is trying to clean up some loose ends related to ongoing experiments.

Dr. Hadwiger has retired at the end of 2020 and did not participate in the project in 2021.

Crop Improvement and Sustainable Production Systems

Project Director
Stefano Musacchi
Organization
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Accession Number
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Annual report Crop Improvement and Sustainable Production Systems

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

This Hatch Umbrella Project seeks to enhance sustainability and profitability of production systems for important crops in Washington State, regionally and nationally. Participants will pursue a collaborative, multidisciplinary strategy bringing together expertise in plant breeding, crop physiology, and rapidly-advancing areas of genomics, phenomics, and bioinformatics, complemented by extension activities in outreach and stakeholder engagement in apple, blueberry, grape (juice and wine), pear, potato, raspberry, sweet cherry, strawberry, and wheat. Our approach combines disciplinary strengths in high-throughput genotyping, quantitative and statistical genetics, bioinformatics, and physiology with plant breeding to support diverse crop improvement programs and maximize our impact on cropping systems, farm profitability, rural farms livelihoods, and food security.

This project combines the breeding activity on several crops with the physiological need of the new and traditional cultivars released on the market. Washington State's environment is almost perfect for tree fruit production. However, climate change is slowly tipping the balance and increasing the risks of loss for tree fruit producers. New, improved apple varieties suitable for the climate condition of Washington are needed to promote and increase consumption and sustain the US apple industry. New wheat cultivars require new sources of resistance to pests and diseases that are overcoming current resistance genes present in the traditional wheat cultivars. Also, barley (the source of malt needed to meet the domestic brewing and distilling industry demand) faces multiple threats that contribute to quality and yield reduction, including

disease, heat, and drought. For this reason, breeders must develop varieties that have broad adaptability that maintains yield and quality. Small fruit plant breeding aims to achieve new summer-fruiting red raspberry cultivars with improved yields and fruit quality, and resistance to some of the most dangerous diseases for this crop: root rot and raspberry bushy dwarf virus.

Apple and cherry breeding can require over 20 years to produce a new cultivar, and molecular tools are critical to enhancing an early screening and providing genetic information about plant material to support confident decisions for its optimal use at any breeding stage. The molecular tools combined with phenomics are towards evaluating traditional and digital phenotypic traits associated with crop performance and quality, which are relevant for crop breeding, crop biology, and precision agriculture applications. The overall goal for such efforts is to allow phenotyping in a cost-effective, high-throughput, and/or accurate manner to improve the overall efficiency in assessing crop traits.

In general, breeders working in a public institution collaborate with physiologists to develop solutions to optimize yield and quality in the field. In this project, many are the areas of physiology involved in such activities. We can list: assessing training systems, pruning, and rootstocks for the new apple cultivar e.g., WA 38; reducing post-harvest losses that are related to environmental stress like heat and developing strategies that maintain high fruit quality while decreasing those losses; agronomical studies on new and existing cultivars of potato; assessment of potato cultivar for viruses and diseases and how they relate to commercial production; strategies of regulated deficit irrigation are investigated to improve water usage and fruit quality composition, in grapes; berry shrivel (also known as SOUR shrivel), a physiological ripening disorder causes significant yield losses and deterioration of fruit quality characteristics are studied in both white and red grape cultivars; development of methods to improve blueberry pollination and fruit set, which is chronically low in production systems in the Pacific Northwest.

Finally, this project aims to improve post-harvest quality through cultivar development and to understand how in-season and post-harvest management and stress affect the storability and quality of seed and processing potatoes. Long-term storage is also a problem for apple grown organically. This is a great challenge due to inconsistent quality post-harvest to supply the market year-round.

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.

Breeding

All the breeding programs at WSU are very active, and their progress can be described in the following way:

Five elite apple selections are being evaluated in the final phase of the WSU apple breeding program. One is likely to be released for commercialization and will likely provide a new, improved eating experience for apple consumers and help sustain the Washington apple industry.

Three cherry selections are in replicated trials to assess the yield and quality; two of them are late-ripening. Late-ripening cultivars have a higher value for growers compared the standard cultivars. In addition, the cherry breeding program identified genetic factors for resistance to fruit cracking and firmness and developed DNA tests for these traits. These tests can be used on young seedlings several years before they begin fruiting, which saves time and can also be used to select superior parents for crosses, which results in superior offspring.

The wheat breeding program develops cultivars with an increased resistance/tolerance to both pests and changing environmental conditions. Improved end-user quality has maintained the current market share and provided the opportunity for increased versatility to expand markets. Both of these have led to more sustainable wheat production systems.

The barley program utilized high throughput genetics, genomics, and phenotypic analyses to develop malt barley varieties adapted to the diverse environments of Washington state. Our genetic characterization and gene discovery research leveraged these breeding efforts to fill important knowledge gaps in understanding plant biology and disease resistance.

The small fruit breeding program uses traditional breeding methods to produce seedlings, make selections, and evaluate selections in multiple stages for yield, horticultural characteristics, disease tolerance, and fruit quality, including firmness, color, flavor, and size. Selections are evaluated for machine harvestability in cooperation with growers to release as a new cultivar.

DNA Informed breeding and Phenomics

The "DNA-informed breeding culminated is activity realized in the RosBREED project, with a cornerstone paper recently published. The results are available on a large-scale nationwide, and a network of breeders and allied scientists collaboratively achieve unprecedented advances in "DNA-informed breeding" of fruit crops in the Rosaceae family (apple, cherry, strawberry, raspberry, and others).

The phenomics efforts were focused on applying unmanned aerial system-based sensing techniques to assess traits such as architecture, crop height, and yield potential on several crops. In addition, approaches such as volatile sensing techniques and Raspberry Pi-based systems were explored for monitoring of traits associated with disease and yield potential, respectively.

Physiology

On the physiological side of this project, the significant progress registered in the fourth year of the project can be summarized as follow:

Trials on 'WA38' orchard establishment and optimization have proved the positive effect of click pruning and girdling on tree training and yield potential.

Development of best management practices by WSU for using netting or cooling systems to reduce fruit losses from fruit sunburn were incredibly important in 2021 during record-breaking heat.

The WSU potato Research Group provides new and updated cultural management for new and existing cultivars that improve grower return, quality, and production efficiencies. Information are available to the industry on websites (www.potatoes.wsu.edu and www.PVMI.org).

Irrigation trial with Riesling grapes found that partial rootzone drying may save up to 30% irrigation water and maintain grape quality in arid climates. Regulated deficit irrigation was somewhat more water-conserving but led to excessive sunlight exposure of the grapes. Thus recommendations can be made regarding alternative irrigation strategies for white wine grapes.

The research on berry shrivel in grapes has trained the grape growers and winemakers in identifying different types of this disorder. While some shrivel types (dehydrated berries) can be used to make wine, SOUR shrivel berries cannot make any valuable products. This project improved the skill levels of viticulturists, including winemakers and growers, to correctly identify SOUR shrivel so that these clusters are not harvested and mixed with other desirable shriveled berries.

Field trials on improving pollination and fruit set in blueberry completed in 2021 showed clustered versus dispersed honey bee hive arrangements increased honey bee abundance on blueberry blossoms. This could be beneficial under sub-optimal weather conditions that limit honey bee foraging and/or for difficult-to-pollinate genotypes. Pollen and nectar analyses show soil nitrogen concentration influences secondary metabolite production and honey bee foraging. Continued work will assess how this may also impact the nutritional profile of pollen and nectar for insect pollinators and if changes in management or bee-keeping practices should be implemented to ensure adequate pollination and hive health. Predictive pollination models are in progress, with preliminary findings suggesting hives within a 500- and 1000-meter radius best predict honey bee abundance on blueberry blossoms relative to field-level stocking densities. Additional work is looking at other landscape variables that may influence pollination. Hive health assessments of honey bee colonies placed in blueberry are ongoing.

Trials to compare post-harvest systems and storage protocols to optimize fruit quality for Honeycrisp and Fuji apples organically grown in warm and cool production sites were carried out in 2021. Researchers found different maturity patterns and disorder development among sites, which were observed during the whole storage period regardless of the storage technology.

Publications 1

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

Washington apple growers have planted over 18 million trees of the WA38 apple (branded as Cosmic Crisp®) since its release in 2017. Many of those young trees started to come into production during this project period.

The new selection of cherry will result in more and better choices of varieties for our growers and consumers.

Wheat growers have new cultivars which are higher-yielding, disease-resistant, and stable against changing environmental conditions, along with improved end-use quality. These lead to more sustainable production systems that maintain productivity to meet the demands of end-use markets and lead to economic stability.

The small fruit plant breeding program continues the annual plant breeding activities that form the basis of successful plant breeding and intensive evaluations of elite red raspberry selections to accelerate their release as cultivars for Washington's red raspberry industry. Additionally, the program leads research testing for IQF quality and examines genomic selection potential for root lesion nematode resistance.

Breeders and germplasm collection curators gained valuable information Info on the identities, pedigrees, and large-effect genetic factors for traits of interest for apple and cherry cultivars, selections, and seedlings, helping them manage their genetically diverse material. Future breeding and genetics trainees gained critical knowledge, skills, and experience.

The Cereal Variety Testing Program provides an accurate side-by-side, unbiased comparison of public and private varieties and advanced breeding lines. Growers can make informed decisions on which varieties are best adapted to their region and thus provide higher yields or reduce input costs, ultimately improving profitability.

The phenomic research will benefit the crop breeders from public and private sectors and various students, researchers, and sensors/instrumentation industries. The findings will also assist crop growers and stakeholders in collaborations with scientists through data-informed decisions.

There are 18 million WA 38 trees planted in WA, as stated above. If we estimate a planting density of 1,500 trees per acre, approximately 12,000 new acres are available. The adoption of specific pruning techniques like girdling and click pruning that increase production up to 20 bins per acre significantly impacts the return per acre for the grower. Several companies have already applied these techniques to newly planted orchards of this high-value cultivar ($500-$800 per bin). This means an increase in return ranging from $10,000 to $16,000 per acre.

The research on netting and cooling systems benefits small, medium, and large fruit producers that aim to produce the best quality fruit in an environment where the risks are increasing under climate change. Without applying these techniques, approximately 30% of the whole apple productions of the State will have damage from sunburn.

Cultivars from the WSU potato program provide producers with improved yields and processing qualities, increased water and fertilizer use efficiencies, and pest resistance, thereby improving the competitiveness of the nation's premier potato-producing region. Improved cultivars will result in a more sustainable, safer food supply.

Showcasing the Riesling trial at a recent field day permitted growers and crop consultants to experience differences among irrigation strategies up close. Adoption of an alternative irrigation strategy may favor quality attributes associated with white wines, enabling wineries to be more competitive in a global marketplace.

The experiments on berry shrivel provide information about a phenomenon poorly known by the growers. In fact, before initiating this project, the grape growers could not distinguish among different types of shrivels. Through this project, a poster with varying kinds of shriveling was disseminated via email to winemakers and viticulturists to avoid confusion and bring awareness.

Different storage protocols for organic apples will be available for WA growers and packers. Information has been delivered thru technical presentations, extension bulletins, and social media. Project collaborators, who provided commercial sites, will directly benefit from the project's activities, such as the correlation of fruit quality and their growing conditions and fruit quality with different post-harvest systems.

Research findings were disseminated via peer-reviewed research articles, a book chapter, popular press articles, stakeholder meetings, conferences, industry webinars, podcasts, and held an advanced malt quality analysis workshop. Information was also presented in undergraduate and graduate-level courses at Washington State University.

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

A significant volume of the Cosmic Crisp® brand apple from the WSU. apple breeding program was produced for the first time in this project period, providing a unique eating experience for US apple consumers.

New cultivars reduce pesticide and fertilizer requirements while maintaining high grain yield, improving both human and environmental health. Stability across changing climates leads to constant production and thus fewer fluctuations in the price of wheat-based products.

One of the ways variety testing information is disseminated is through a variety selection tool on the extension website. A mobile app was developed in 2021 to allow easier access on mobile devices and access to the data offline.

The small fruit breeding program works to incorporate machine harvestability, excellent fruit quality, and root rot tolerance into its elite germplasm. Excellent cultivars are the basis for raspberry production and consumer availability.

Improved potato cultivars with enhanced pest and disease resistances and quality and production efficiencies will reduce fertilizer and pesticide inputs, resulting in a more sustainable, safer food supply. New cultivars often have higher protein and phytonutrient content, providing consumers with a more nutritional food source.

Stakeholders benefited from our activities through collaborative efforts fostered by interactions allowing us to target breeding efforts to meet the challenges of production and the liquid arts. The WSU. malt quality analysis lab provides services to the industry to analyze grain and malt and an annual malt quality workshop that is open to the public.

DNA profiling technology developed in the RosBREED project was provided to the public, collection managers, and the National Parks Service to determine the cultivar identities and pedigrees of hundreds of old apple trees in the US landscape, collections, and distribution networks. The information reveals and establishes historical ties between people and fruit cultivars and enhances confidence in the use of the material.

The public benefits from enhanced vineyard irrigation strategies through the conservation of valuable water resources and by having access to better white wines.

A poster enabled the growers to identify SOUR shrivel clusters and drop them before harvest improving fruit quality. Clusters afflicted with other shrivels types can be used for making wine.

Insect pollinators are essential to produce this high-value, nutritious berry crop. Ensuring adequate pollination ensures the continued success of blueberry operations, production of this crop, and resultant availability of blueberry to consumers. The resultant information is also used to understand factors that can diminish or enhance the health of both managed and wild pollinators and train the next generation of scientists on pollination systems in horticulture.

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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.

We disseminate information through research articles, popular press, podcasts, grower meetings, and participation in conferences. All these also provide training opportunities and hands-on participation within the breeding and research programs. The project will continue to develop new cultivars to meet future demands. The project supported both undergraduate and graduate education as some of the findings from the research activities were included as a part of course materials and training programs.

We encounter some specific problems the malt barley quality parameters in 2021 have been challenging and exacerbated by climate change—the existential threat of our time. With the predicted shortages of quality malting barley in the future due to extreme temperatures, drought, and novel disease patterns, we are establishing the winter barley breeding program as winter barley alleviates many of these problems.

The student-run Palouse Wild Cider apple breeding program (est. 2014) provided hands-on experiential learning opportunities for graduate and undergraduate students at the WSU main campus. The graduate course "DNA-Informed Fruit Breeding" in spring 2021 trained six students in knowledge, skills, and experience in this new field that they could receive nowhere else.

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Functional Genomics in Animal Improvement, Food Safety and Human Health

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Regulatory functions of genes and/or gene networks in physiology and pathology

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

Research projects conducted by the Animal Biology and Biomedicine group at Washington State University address important health and disease issues relevant to animal growth, embryo development, progeny survival, reproductive success and welfare maintenance. The goal of our research is to understand genetic information flows from genome to phenome and thus develop novel strategies for livestock and aquaculture industries to improve productivities and reduce economic loss.

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 Du laboratory studies maternal impacts on embryonic muscle and adipose tissue development. Recent studies clearly show that maternal nutrition, exercise and physiological conditions have profound impacts on embryonic and fetal development, but mechanisms remain to be defined. We have been focused on skeletal muscle and adipose tissue development, because these tissues are critically important for maintaining metabolic health, as well as improving the efficiency of animal production. We have been using mice and cultured cells for our studies, and discovered that maternal nutrition affects oocyte health, which alters embryonic development, and has long-term impacts on offspring metabolic health.

The Lavine laboratory focuses on gender difference in beetle horn development during evolution. We have tried to understand the origins of these novel phenotypes and discover the gene x environment interactions that coordinate the horn developmental divergence between sexes. Based on whole animal signals, cell-cell signals and within-cell signals, we have evidence to show that endocrine factors, developmental patterning genes and sex-specific gene expression regulate beetle horn size, shape and location.

The Law laboratory is interested in the molecular mechanisms that guide fetal germline development, which sets the stage for animal and human fertility long into reproductive ages. Our goal is to identify the genes that regulate the onset of both male and female gamete production to ultimately shape reproductive performance and progeny health. In the past year, our research efforts have identified a family of factors that are necessary for the onset of sperm production in males. Furthermore, we have begun to evaluate the epigenetic regulation of germline development and its role in adult fertility outcomes. Collectively, we have identified critical genes for germline development and will continue mechanistic studies.

The Phelps laboratory is focusing on the muscle biology of trout and salmon by investigating the function of the activin signaling pathway which is one of the most important muscle growth pathways in vertebrates. We performed a pathway wide gene expression analysis across 24 tissues, many muscle types and developmental stages. We also have created 6 CRISPR gene edited animals that have mutations in key members of the pathway to better understand their function. We are also

performing whole transcriptome analysis of salmon from multiple key tissues such as brain, muscle, and reproductive organs to study how the body changes during its maturation process. In addition, we are also investigating problems such as premature maturation while developing tools to create sterile offspring to reduce the impact of fish escapements.

The Zhu laboratory determines the beneficial effects of dietary bioactive on gut microbiota and intestinal health. Inflammatory bowel diseases (IBDs) are chronic and relapsing intestinal inflammation diseases and are associated with dysfunction of the interstinal epithelium, which are common in the Western world. Up to now, available therapeutic options focus primarily on suppressing inflammation, allowing only for management but not complete recovery. Clinical treatments reduce intestinal lesions but there remains a high chance of recurrence. Our lab has been evaluating dietary food bioactive as preventive approaches to reduce the occurrence of IBD and exploring the underlying mechanisms. We have been using mice and cultured cells for our studies, and discovered that dietary supplementation of alpha-ketoglutarate and other bioactive can be an alternative approach for the prevention or treatment of colitis that is common in Western societies.

The Jiang laboratory has a long history of collecting alternative transcript resources in various species with goals to understand how RNA variants make it possible for a finite genome to coordinate an infinite phenome in response to internal, external and universal environments. In fact, many genes use alternative promoters, splicing and polyadenylation to function qualitatively, quantitatively and even epigenetically. In cattle, we used a total of 228 RNA-seq datasets released by twelve laboratories involving corpus lutea (16 samples), embryos (61 samples), granulosa cells (72 samples), oocytes (12 samples), ovary (34 samples) and theca cells (33 samples) for assembly of alternative transcripts. On the other hand, we also carried out whole transcriptome termini site sequencing (WTTS-seq) to capture alternative polyadenylation events among different types of cells and tissues. The combined results are helping us identify both protein-coding and non-coding transcripts that regulate health and diseases in animals.

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

Studies in **the Du laboratory** showed that maternal nutrition and physiological conditions have profound impacts on embryonic and fetal development, which generates long-term impacts on offspring health. Knowledge obtained will help obese maternal women to improve fetal development and the health of next generations. For beef producers, our studies provide guidelines for the nutritional management of cows during pregnancy in order to improve the performance of offspring.

The collective findings generated in **the Law laboratory** are contributing to the growing body of evidence, relevant to researchers, veterinarians, and clinicians, that perinatal development is a critical window for long-term health outcomes, including fertility, across mammalian species. This information can be used for further research studies as well as directing informed, health-conscious decisions for veterinarians and clinicians.

The research in **the Phelps laboratory** has been invited to be presented at two National American fisheries society meetings, and two international muscle biology meetings in Italy and Costa Rica. We also were invited to seminar series at the University of Minnesota, University of Alaska Anchorage, the University of Washington, and Washington State University. These interactions were invaluable to disseminate ideas about aquaculture, muscle biology and genome editing technology. We have also established close ties with industry trout farms, regularly sharing our results with these groups and encouraging collaboration.

The Zhu laboratory has been examining the impacts of bioactive compounds on gut microbiota and epithelial health using inflammatory bowel disease as a model. Given that impaired intestinal barrier function or leaky gut is the key etiologic factor of metabolic, autoimmune, and other diseases, knowledge obtained helps the general public choose healthy foods and food industries to produce nutritious and safer products.

The Jiang laboratory has been actively involved in the bovine genome and pangenome annotation consortia by contributing materials, methods, tools and resources to advance genome sciences, biotechnology and their application in improvement of production and wellbeing of beef and dairy cattle. Three invited talks were given on the consortium research activities and progresses: 1) The bovine pangenome consortium, 2) Bovine transcriptome annotation using integration of multi-omics data and 3) Functional annotation of the bovine genome were presented at the 38th International Society for Animal Genetics Virtual Conference in 2021.

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

Maternal nutrition and exercise are highly manageable. As a result, the data generated in **the Du laboratory** will provide guidelines for maternal nutritional management and promotion of moderate maternal exercise before and during pregnancy in order to improve the health of next generations. In addition, maternal nutritional management can be used for improving productivity of farm animals.

Dr. Law believes that the broader public will benefit from improved reproductive capacity from production animals once we better understand the critical components for germline development that influence reproductive outcomes.

Dr. Phelps has presented talks to K-12 classrooms and community members interested in trout/salmon biology and genome editing technology. These interactions have benefited the scientific and region community by educating them about salmonid aquaculture and the utility of new genome editing technology. We also host local high school students in the lab to introduce them to advanced scientific research.

Gut epithelial barrier function is critical for our health. A leaky gut has been identified as a critical etiological factor for a number of common inflammatory diseases, including Inflammatory bowel diseases, type I diabetes, and food allergy. The findings discovered in **the Zhu laboratory** will provide guidelines for nutritional management for individuals with intestinal diseases.

As an invited speaker or an invited plenary speaker, **Dr. Jiang** gave three presentations in 2021: 1) Biodiversity: does RNA diversity matter (8th International Symposium of Innovative Bioproduction Indonesia on Biotechnology and Bioengineering 2021); 2) Advancing Genome to Phenome Research in Swine: Progress and Perspectives (9th International Congress: Veterinary Science and Profession. University of Zagreb) and 3) Mapping of alternative polyadenylation sites to *Rattus norvegicus mRatBN7.2* (Rat Genome Annotation Consortium Monthly Update). As such, we have disseminated our knowledge and technology to broad communities in Asia, Europe and North America with various scientific fields.

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.

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Developing Food Processing, Safety, Quality, and Supply Solutions for Production of High Quality and Safe Food

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Altering and improving wine produced in Washington and ultimately the United States

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

In the food quality and food processing portion of this project, research specifically focuses on wine grapes and how to alter and improve wine produced in Washington and ultimately the United States.

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.

Food Quality/Food Processing:

1. Evaluated impact of grape maturity and alcohol concentration on sensory impacts of wine to help winemakers and grape growers better understand how picking decisions alter wine quality.

2. Developed rapid low cost non-destructive methodology for monitoring sugar and alcohol during fermentation of wine.

3. Evaluated phenolics during aging to better understand chemical compositional shifts that have significance to sensory evaluation of wine.

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

Winemakers and grape growers have deeper insight into how basic fruit and wine attributes alter wine sensory and can be better and informed decisions about grape ripeness. Winemakers can also access faster and more portable methods for evaluating the progress of their fermentation.

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

The public enjoys the improvement of wine quality in the United States.

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.

COVID has made many in-person outreach activities more difficult to accomplish if not impossible.

Sensory evaluation of experimental wines has also been delayed to due Pandemic related issues.

Publications:

1. Fuller, H., Beaver, C. W., Harbertson, J. F. (2021). Alcoholic Fermentation Monitoring and pH Prediction in Red and White Wine by Combining Spontaneous Raman Spectroscopy and Machine Learning Algorithms. *Beverages, 7*(78). https://www.mdpi.com/2306-5710/7/4/78 Peer Reviewed.

2. Weilack, I., Harbertson, J. F., Webber, F. (2021). Effect of Structural Transformations on Precipitability and Polarity of Red Wine Phenolic Polymers. *American Journal of Enology and Viticulture*. Peer Reviewed.

3. Frost, S., Sanchez, Merrell, C., J. Larsen, R., M. Heymann, H., Harbertson, J. F., (2021). Sensory evaluation of Syrah and Cabernet Sauvignon wines: effects of harvest maturity and prefermentation soluble solids. *American Journal of Enology and Viticulture, 72*, 36-45. Peer Reviewed.

Research into the specialized needs of older adults , the feeding needs of children with Down syndrome, and identifying off-aroma issues of wine and potato products

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

Our project addressed a number of problems in the food and beverage industry. First, our research addressed the specialized needs of older adults in the development of appropriate nutritious and safe meals for this population. We also addressed the feeding needs of children with Down syndrome by determining which food textures were easier for children with Down syndrome to manage. Finally, our project addressed the off-aroma issues of wine and potato quality, developing a new rapid and accurate method of identifying off-aromas in these products, allowing for early remediation.

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.

One of our goals was the early detection of off-aromas/faults in wine and frozen potato products. We made good progress toward this goal as we developed analytical methods (electronic tongue, gas chromatography-mass spectrometry) to detect these compounds. We now plan on implementing these methods in food products to assess the robustness and reliability of these methods. Another goal was to develop food products for specific populations, including older adults and children with Down syndrome. We were successful in this goal as we have identified important elements to older adults in their meals (i.e. Mediterranean taste theme, not spicy, chicken or alternative protein source). Within our studies in children with Down syndrome, we develop a home-use test that can be used to gather information regarding meal behaviours and preferences of this hard-to-reach population. We have also started to identify difference in oral processing between children with Down syndrome and typically developing children, with this work continuing.

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

Food processors, fruit and vegetable growers- This group will benefit from our research into identification of off-aromas in frozen potato products, specifically the development of methodology to detect these off-aromas.

Winemakers and brewers– This group will benefit from our research using the electronic tongue to offer early detection of wine faults. This would allow for early remediation of these wine faults, thereby saving the wineries some financial losses. Our work within craft beer also identified desirable sensory properties of beer, useful for those producing beer.

Food manufacturing companies – Our research with older adults and children with Down syndrome offers specific findings that can be incorporated into future food product development for these populations. Within the older adults population, we found the components of meals that older adults desire, along with specific finding regarding salt sensitivity. For the children with Down syndrome, we found that these children preferred dissolvable and crispy food textures, along with cheesy flavors, information that can be used in the development of food products for this population.

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

For our food quality work, with earlier detection of off-aromas, the broader public will enjoy higher quality products. Also, with the extensive research that we have done in the area of ready to eat meals and microwave processing, safe and nutritious meals, with extended shelf-life, are available to consumers.

Our research offers broader benefits to the Down syndrome community, specifically parents, clinicians and practitioners who live and work with children with Down syndrome. We can recommend specific food textures that can be put into practice and help those who struggle with food texture sensitivities.

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.

1) Ross, C.F., Surette, V., Bernhard, C.B., Smith-Simpson, S., Lee, J., Russell, C.G. and Keast. R.S. 2021. Development and application of specific questions to classify a child as food texture sensitive. Journal of Texture Studies. http://doi.org/10.1111/jtxs.12627

2) Paup, V. D., Cook-Barton, T., Diako, C., Edwards, C. G., & Ross, C. F. 2021. Detection of red wine faults over time with flash profiling and the electronic tongue. Beverages, 7(3), 52-60. https://doi.org/10.3390/beverages7030052

3) Aplin, J. J., Paup, V. D., Ross, C. F., & Edwards, C. G. 2021. Chemical and sensory profiles of Merlot wines produced by sequential inoculation of Metschnikowia pulcherrima or Meyerzyma guilliermondii. Fermentation, 7(3), 126-132. https://doi.org/10.3390/fermentation7030126

4) Montero, M. L., Garrido, D., Gallardo, R. K., Tang, J., & Ross, C. F. 2021. Consumer acceptance of a ready-to-eat meal during storage as evaluated with a home-use test. Foods, 10(7), 1623-1633. https://doi.org/10.3390/foods10071623

5) Garrido, D., Gallardo, K., Ross, C.F. Montero, M. and Tang, J. 2021. Does the order of presentation of extrinsic and intrinsic quality attributes matter when eliciting willingness to pay? Journal of Food Science. 86 (8): 3658-3671. http://doi.org/10.1111/1750-3841.15825

6) Qu, Z., Tang, J., Sablani, S., Ross, C. F., Sankaran, S., and Shah, D. 2021. Quality changes in chicken livers during cooking. Poultry Science. 101316. https://doi.org/10.1016/j.psj.2021.101316

7) Garrido, D., Gallardo, K., Montero, M. and Ross, C.F. 2021. The effect of intrinsic and extrinsic quality on the willingness to pay for a convenient meal: A combination of home-use test with online auctions. Journal of Sensory Studies. 36(5), e12682. http://doi.org/10.1111/joss.12682

8) Surette, V.A., Bernhard, C.B., Smith-Simpson, S. and Ross, C.F. 2021. Development of a home-use method for the evaluation of food products by children with and without Down syndrome. Journal of Texture Studies. https://doi.org/10.1111/jtxs.12601

9) Craine, E., Bramwell, S., Ross, C.F., Fisk, S. and Murphy, K. 2021. Strategic malting barley improvement for craft brewers through consumer sensory evaluation of malt and beer. Journal of Food Science. 86 (8): 3628-3644. https://doi.org/10.1111/1750-3841.15786

10) Qu, Z., Tang, J. Liu, F., Sablani, S., Ross, C. F., Sankaran, S. and Tang, J. 2021. Quality of green beans (Phaseolus vulgaris L.) influenced by microwave and hot water pasteurization. Food Control. 124: 107936. https://doi.org/10.1016/j.foodcont.2021.107936

11) Ross, C.F. 2021. Considerations of the use of the electronic tongue in sensory science. (Invited submission). Current Opinion in Food Science. 40: 87-93. https://doi.org/10.1016/j.cofs.2021.01.011

Type

Projects / Programs without a Critical Issue

Not Provided

Projects / Programs

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