Extension Education

Commentary on Extension Programming: An Online Platform for Area-Wide Management of Western X-Disease Extension Program

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JEL Codes: A30, Q16, Q57
Keywords: Area-wide pest and disease management, decision aid tool, Extension services evaluation

Abstract
The Extension program discussed in this commentary article was developed using a logic model to provide an economic analysis of Western-X disease (WXD) management at the farm and landscape levels. This program entered the Graduate Student Extension Competition organized by the Agricultural and Applied Economics Association (AAEA). It consisted of a simulated presentation to sweet cherry growers on the economics of tree removal as a disease management practice. The program's delivery and communication strategies include an online platform, fact sheets, research articles, conference presentations, and workshops. This commentary shows how young professionals can create a successful program using a logic model.

1 Introduction

The Extension program consists of providing an online platform designed as a decision-aid tool to support the implementation of area-wide management (AWM) of Western-X disease (WXD). The development of the online platform stems from a logic model, ensuring that the Extension program addresses a clearly defined problem, identifies the target audience affected, sets specific objectives, and designs activities to communicate research-based information to improve the decision-making process effectively. This commentary explains how an online platform offers stakeholders (e.g., growers, pest management consultants, packinghouse representatives, and Extension educators) a transparent and open access pool of information about the impacts of implementing an AWM Extension program. This online platform is based on a bioeconomic model of WXD management developed by Ghorbani et al. (2024). In this article, we present a simplified version of the model to evaluate the impact of disease management using an Excel spreadsheet.[1]

The overall purpose of this article is to show the potential benefits of using an online platform in an Extension program. Plus, we discuss how we use a logical model to develop successful Extension programs around applied research. The objectives are to (1) summarize the proposal for the Extension program submitted to the AAEA Extension Competition committee and (2) provide a detailed discussion about constructing an Extension program using a logic model.

2 Extension Program Summary

The program proposes a web-based platform that provides research-based information to reduce the uncertainty surrounding the effectiveness of AWM and evaluate participants' commitment in real time. The program contributions are threefold. First, the web-based platform provides a customized research-based recommendation on the optimal tree removal rates based on a bioeconomic simulation that inputs

[1] An open access version of the Excel file is available as supplementary material to this paper.

the number of participants in the program, disease pressure in the area, age distribution of trees in the area, and other important information. Second, participants commit to share factual information about the number of removed diseased trees in their orchard, which can be verified using satellite imagery and remote sensing. Third, the platform emphasizes the timely removal of infected trees and shows the potential farm-level effects of successful AWM by comparing economic and ecological measures from participating and non-participating areas.

2.1 The Problem

Sweet cherry growers (among other growers cultivating Prunus species such as peaches, nectarines, plums, and so on) on the west coast face the WXD. This infection negatively affects sweet cherries, turning them into non-marketable fruit due to the small and misshapen fruit, poor color, and lack of flavor/bitter fruit. The only known vectors are some species of leafhoppers that feed on infected trees carrying the WXD phytoplasma through the orchard block (DuPont et al. 2024). The successful management of insect-vectored plant diseases, where the vector is highly mobile and feeds on a wide range of host plants, often requires intervention coordinated on a regional scale (Chandler and Faust 1998; Faust 2008). The most common challenge AWM programs face is the uncertainty about participants' commitment. For example, an AWM program that was established in 2010 to limit the spread of huanglongbing disease in citrus orchards of Florida eventually failed due to insufficient involvement by growers (Singerman, Lence, and Useche 2017; Singerman and Useche 2019; Lence and Singerman 2023). Pesticide applications, cultural treatments, and infected host removal are examples of coordinated actions, and AWM programs can include any/all of these actions. WXD management focuses on preventing the spread by controlling leafhoppers and removing infected trees. However, growers tend to keep the infected trees longer to maximize current revenues at the cost of long-term disease damage due to keeping the infection sources. Uncertainty over disease control by other growers can reduce growers' incentives to invest in disease control. A tool that decreases uncertainty about participants' commitment and showcases the farm-level economic impact of the timely removal of infected trees is a significant step toward increasing participation in AWM programs.

2.2 Bioeconomic Analysis

We provide a tool to support farm-level decisions regarding the economics of removing infected cherry trees by evaluating the benefits (i.e., avoiding future infections and related damage and costs) and costs (e.g., tree removal cost, forgone yield) of removing infected trees.[2] For illustration purposes, we discuss how to evaluate the impact of disease management using an Excel spreadsheet (Supplement 3).[3] The "Assumptions-Analysis" tab presents the list of constant values that can be modified according to the characteristics of orchards and growers. We assume that an acre of orchard contains 605 trees. The estimated yield is zero during the first two years of establishment and peaks over time and remains constant at 19,200 lb./acre from Year 6 onward. Regarding disease dynamics, we assume that 5 percent of healthy trees become infected due to incoming disease pressure from neighboring orchards in the area. An additional 3 percent of healthy trees become infected through infield infection if the symptomatic trees are left in the orchard. Also, we assume that 2 percent of infected trees become symptomatic each year. Regarding the disease yield penalty, we assume that infected and symptomatic trees produce 10 percent and 50 percent less marketable cherries than healthy trees. In the attached spreadsheet, rows 24–28 present the yield values for infected and symptomatic trees.

[2] Please refer to K. Ghorbani et al. 2024 for more detail.
[3] We used economic variables (price, yield, costs) from 2022 Skeena cherry enterprise budget, which can be found at https://ses.wsu.edu/enterprise_budgets/.

2.2.1 "No Management" Scenario

In this scenario, growers do not remove symptomatic trees, and the region has no AWM program. Thus, the infection rate under this scenario equals 8 percent, aggregating the impact of disease pressure carried into orchards from other orchards and infield disease pressure driven by the symptomatic trees if not removed. We calculate the number of infected trees by multiplying the number of healthy trees by the infection rate each year. We deduct the number of infected trees from those healthy trees to calculate the following year's number of healthy trees. We calculate the estimated net yield output by multiplying the number of trees in each health status (healthy, infected, or symptomatic) by the corresponding estimated health-status-specific yield.

$$net\ production = \sum_{n=0}^{n(s)} \sum_{s}^{S} n \times y(s)$$

where n(s) is the number of trees in each state s, S is the set of health status, and y(s) is the yield of trees at state s. For example, the estimated net production of an orchard in Year 7 equals the number of healthy trees (367) times the yield of healthy trees (32 lb./tree), plus the number of infected trees (238) times the yield of infected trees (29 lb./tree), plus the number of symptomatic trees (5) times the yield of symptomatic trees (16 lb./tree). Gross returns equal the product of the yield (lb./acre) and price ($/lb.). We calculate the net present value (NPV) by deducting the operational cost from the gross return, discounting this value for each year, and summing it over 25 years. The estimated NPV of an acre of cherry orchard with disease and no management over 25 years equals $141,196.

2.2.2 Scenario 1: Removal of Symptomatic Trees Without Replanting

There is no AWM in this scenario. Still, growers remove all symptomatic trees each year, suggesting that the only source of disease spread in an orchard is the 5 percent incoming infection rate. We assume that the cost of tree removal is $33/tree and add the total cost of symptomatic tree removal to the operating expenses. All other conditions remain the same as in the "no management" scenario. The orchard's NPV is $143,195/acre over 25 years, highlighting that removing symptomatic trees results in 1-percent higher NPVs than the no-management scenario.

2.2.3 Scenario 2: AWM

There is an AWM program, and every participating grower commits to removing all symptomatic trees in this scenario. As a result, we assumed that the incoming infection rate would drop from 5 percent to 2.5 percent (Personal communication with Dr. Scott Harper). All other conditions remain the same as "Scenario 1." The NPV increases to $152,132/acre. This 7-percent NPV increase, relative to Scenario 1, is the benefit individual growers get from implementing an AWM program.

2.3 The Online Platform

The advantage of the online platform is that the recommendation is tailored to specific grower and orchard characteristics. Thus, the online platform consists of two main sections. The first section focuses on acquiring operations and orchard block characteristics, such as tree density, block size in acres, maximum yield per tree, etc. (Figure 1). We follow the Washington State University (WSU) crop budget and consider a 5-percent discount rate, but this value can be adjusted by the user.

The second section of the platform uses bioeconomic simulations. It provides farm-level recommendations about tree removal decisions by reporting NPVs for different ranges of tree removal based on the operation and orchard's characteristics and under two assumptions about disease pressure

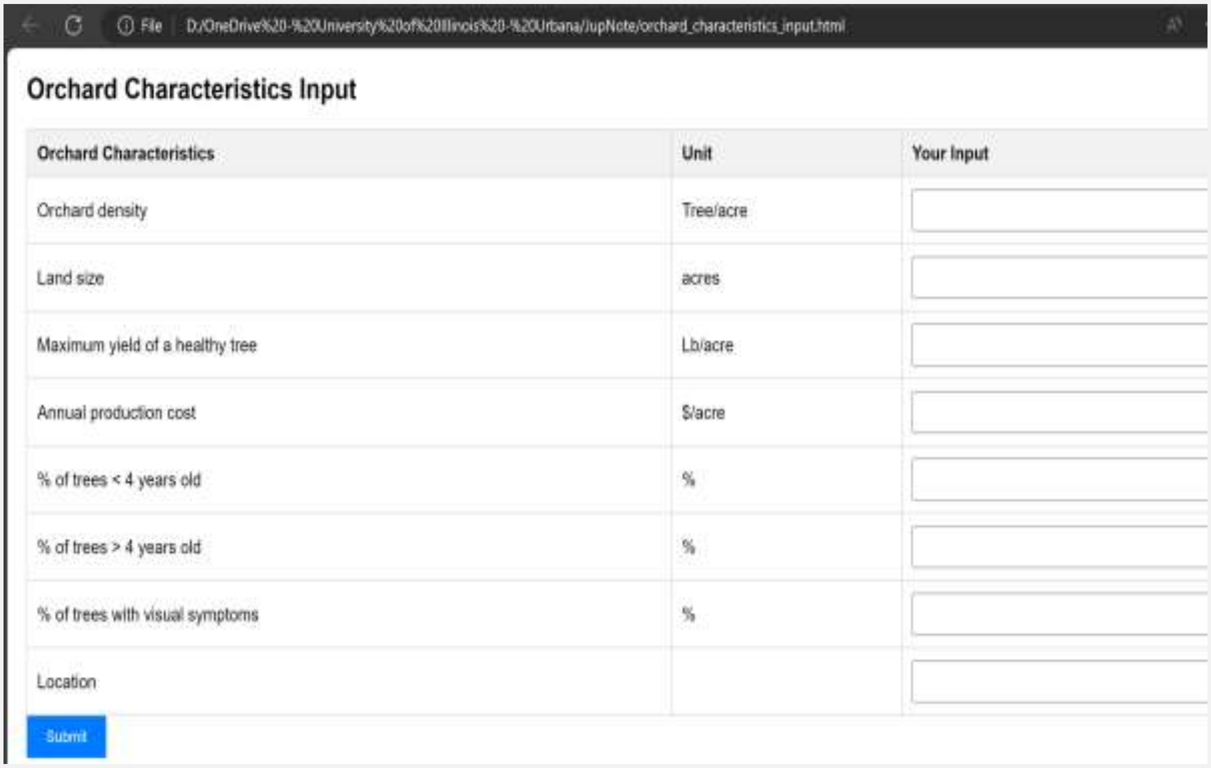


Figure 1: The First Section of the Online Platform.

in the area (Figure 2). The last section provides information about the economic impact of AWM on grower's NPV.

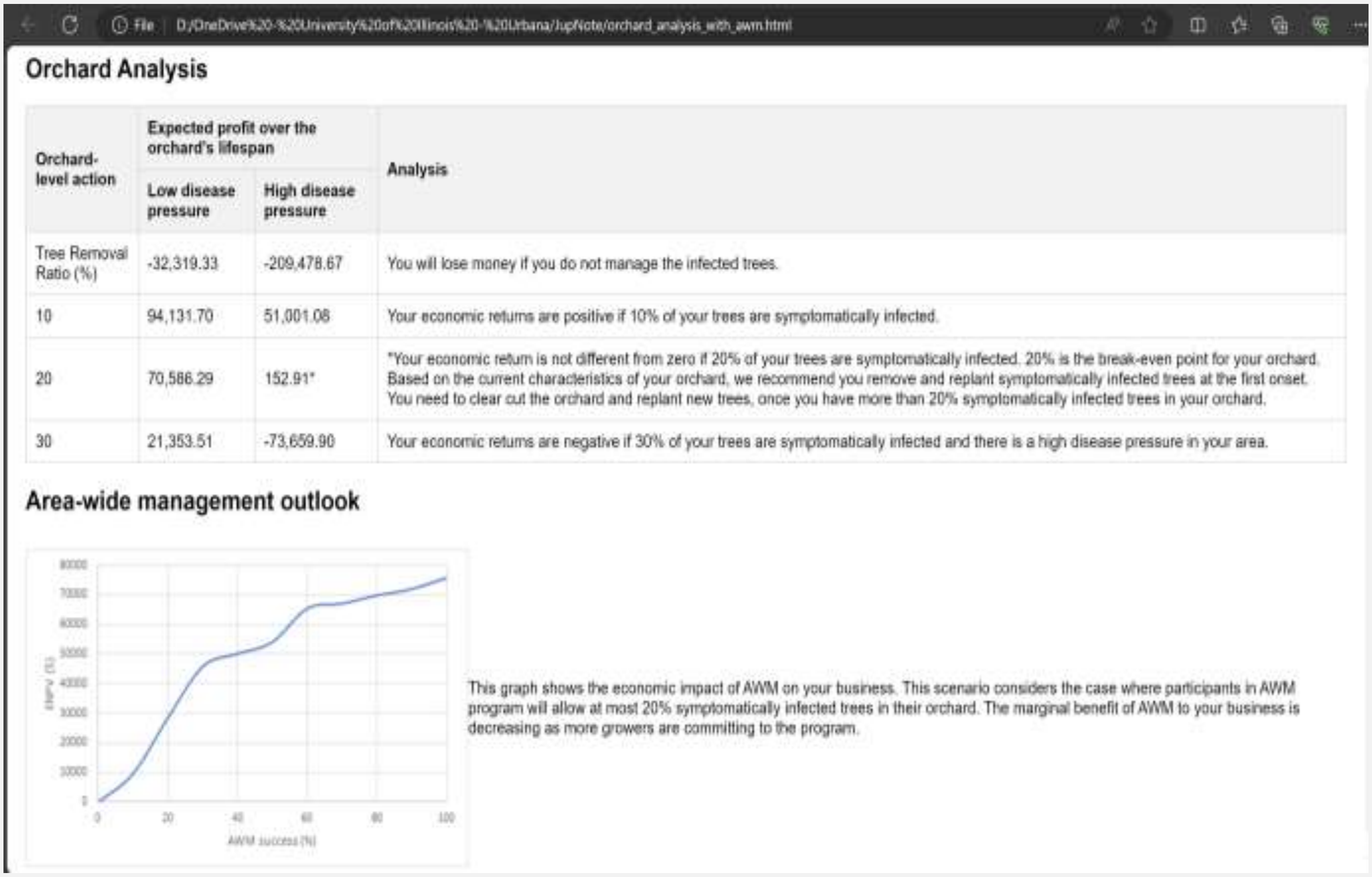
For illustration purposes, the results in this section are presented for a representative sweet cherry grower in Washington State. The choice of Washington State is that this state has been the top producer of sweet cherries over the last fifteen years in the United States (Ghorbani and Mashange 2024). Plus, the ecological and economic data used in the bioeconomic model was available for Washington State. However, the results and development of the Extension program can be used to develop similar estimations and programs across the sweet cherry growing regions of the United States.

3 Extension Program Development

The proposed Extension program delivers an online tool developed using a logic model. The online tool presents the results of a bioeconomic WXD management model and information about the impacts of joining an AWM. This work was presented at the AAEA Graduate Student Extension Competition. The logic model provides a blueprint for constructing an effective Extension tool to communicate research findings. The logic model in Figure 3 served as an example of effectively communicating the results of a bioeconomic model of crop disease management through an online platform using WXD management.

3.1 Situation

The current situation of the proposed Extension program is that cherry growers decide to opt into an AWM program that requires growers to remove symptomatic trees from their orchards to manage the disease on their orchards and others' orchards. At the farm level, growers might want to delay removing infected trees to recover costs from the marketable cherries. At the landscape level, previous AWM experiences show that grower uncertainty about the commitment of other growers to program



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Orchard Analysis

Orchard-level action	Expected profit over the orchard's lifespan		Analysis
	Low disease pressure	High disease pressure	
Tree Removal Ratio (%)	-32,319.33	-209,478.67	You will lose money if you do not manage the infected trees.
10	94,131.70	51,001.08	Your economic returns are positive if 10% of your trees are symptomatically infected.
20	70,586.29	152.91*	*Your economic return is not different from zero if 20% of your trees are symptomatically infected. 20% is the break-even point for your orchard. Based on the current characteristics of your orchard, we recommend you remove and replant symptomatically infected trees at the first onset. You need to clear cut the orchard and replant new trees, once you have more than 20% symptomatically infected trees in your orchard.
30	21,353.51	-73,659.90	Your economic returns are negative if 30% of your trees are symptomatically infected and there is a high disease pressure in your area.

Area-wide management outlook

This graph shows the economic impact of AWM on your business. This scenario considers the case where participants in AWM program will allow at most 20% symptomatically infected trees in their orchard. The marginal benefit of AWM to your business is decreasing as more growers are committing to the program.

Figure 2: The Second Section of the Online Platform.

requirements can be a barrier to AWM success. The online platform proposed in this Extension program benefits from the publicly available satellite imagery datasets to verify growers' commitment to the program and provide farm-level economic analysis of WXD management through individual tree removal.

3.2 Inputs and Outputs

The inputs of this program include time to develop activities and resources such as consulting meetings with faculty members in the College of Agricultural, Human, and Natural Resource Sciences (CAHNRS) at WSU, grower meetings, and other stakeholders. These resources guide at two levels. First, faculty and growers' comments help calibrate the decision model to the most up-to-date scientific and experimental results. Second, feedback helps to develop an online platform that best fits users' needs. Funding from U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) and collaboration with graduate student researchers from the School of Economic Sciences at WSU are other inputs of this program.

The outputs of this Extension program revolve around developing hands-on activities to ensure that growers are familiar with the features of online platforms. Plus, participants' engagement in these activities evaluates how well the platform corresponds to growers' needs and how well the platform communicates scientific narration to the target audience. This Extension program is designed to reach a wide range of audience members, including cherry growers, Extension agents, and fellow professionals in academia.

Situation: Once infected with Western-X disease, growers need to remove the infected tree. However, growers tend to delay removing infected trees to recover costs from the marketable cherries. The longer growers keep an infected tree in the orchard, the higher the risk of disease spreading within an orchard and through a growing region. As a result, disease management requires landscape-level cooperation between growers in cherry producing regions and the major drawback for growers to participate in area-wide management (AWM) program is the uncertainty about the commitment of the participants to program standards.

Inputs	Outputs		Outcomes – Impact		
	Activities	*Participants*	*Short*	*Medium*	*Long*
Washington State University College of Agriculture, Human, and Natural Resources (WSU-CAHNRS) Extension faculty Commitment and engagement from stakeholders (i.e. Northwest Cherry Grower Association) Graduate student researchers from the School of Economic Sciences at Washington State University Funding from USDA-APHIS for the first three years and $1 annual subscription for the following years Advice and coordination from/by stakeholders and partners	Short courses/workshops taught at Washington State University Online training videos and exercises hosted on the WSU-CAHNRS Extension website. Webinars for interactive discussions on updates of the platform Platform updates dissemination (presentations, webinars, workshops, fact sheets, etc.) Roundtable discussion hosted at WSU-CAHNRS	Northwest Cherry Grower Association members, Northwest Horticultural council, groups of growers, disease management consultants WSU-CAHNRS Extension faculty and graduate students Extension faculty from other universities in states proposing AWM (e.g., Florida, California) Regulatory agencies in Washington (Washington State Department of Agriculture)	Increased awareness about the role of tree removal in controlling Western-X disease. Increased understanding of economic impact of tree removal. Increased awareness about the importance of area-wide management in controlling Western-X disease. All are direct results of the online and in-person courses and workshops that will be taught. Increased and richer discussions between growers and Extension officers on strategic decisions.	Enhanced decision evaluation in strategic planning. Increased confidence of growers and strategic decision makers in AWM program by evaluating the commitment of participants to the program. Empirical economic efficiencies gained in disease control options. More growers are drawn to tree removal options. Formation of initial AWM pockets throughout the growing region. Validation of growers' commitment to AWM protocols and evaluation of the AWM program.	Reduction in the spread of leafhoppers and Western X disease in cherry growing areas. Regional and national adoption of the platform. Strengthen the area-wide disease management programs across the U.S.

Assumptions

1) Platform is taught, and through experience, viewed as intuitive by users
2) Growers and decision makers found the platform beneficial for making strategic disease management decisions
3) Continued support from Extension faculty members at Washington State University
4) Participants have a basic understanding of cost-benefit analysis and disease management strategies.

External Factors

1) Perceptions and beliefs of growers and decision makers
2) Growers' familiarity with online decision aid platforms
3) Policy changes on the information disclosure of satellite imagery

Figure 3: The Logic Model of the Online Platform for Area-Wide Management of Western-X Disease.

3.3 Outcomes
The next step is to measure the program's short-, medium-, and long-term impact. Short-term impacts involve seeing change in the areas of knowledge, attitudes, skills, and aspirations (Israel 2001). Because participation in Extension programs is voluntary, the number of participants, intensity of participation, and satisfaction with the program are also considered by some experts to be aspects of short-term outcomes (Hatry 2006). The short-term goals of this program are to increase awareness of WXD management by increasing knowledge about the economic benefits and costs of farm-level removal of infected cherry trees, as well as the importance of landscape-level coordination in disease management.

The medium-term goals of this program are to enhance decision evaluation in strategic planning by increasing the confidence and willingness of growers and strategic decision-makers to evaluate the use of landscape-level coordination of disease management. Over a medium time range, realized economic gains from disease control attract more growers to commit to an AWM program, resulting in AWM clusters emerging throughout a growing region.

Last, the long-term goal is to reduce WXD economic damage by reducing the spread of leafhoppers in cherry-growing areas. Furthermore, adopting the online platform on regional and national levels achieves the long-term goal of reducing WXD economic damages by strengthening the area-wide disease management programs across the United States.

3.4 Assumptions and External Factors
It is important to identify the assumptions made regarding this program and its participants and identify external factors that may impact its effectiveness. The assumptions are that participants have a basic understanding of cost-benefit analysis and disease management strategies, that the platform benefits from the continued support from Extension faculty members, and that users learn more about the platform by using it. In addition, the external factors that could affect the success of the Extension program are perceptions and beliefs of growers and decision-makers, growers' familiarity with online decision-aid platforms, and policy changes on the publicly available satellite imagery information.

4 Extension Program Evaluation
The evaluation plan aims to assess the effectiveness, usability, and impact of the AWM online platform. Regarding the web-based platform, we will conduct an evaluation survey of people who have used the tool to get their feedback on what is and is not working and how we could improve it. Plus, this survey allows us to assess the initial level of knowledge. A follow-up survey will be conducted after one year to reflect on the platform's shortcomings and gauge growers' understanding of the AWM program. In addition, we will prepare a short quarterly report for presentation at the growers' meeting, which will further increase communication between growers and the AWM support team. Also, we plan to prepare content suitable for social media (i.e., Facebook, Instagram, X, and YouTube) to increase outreach. Moreover, we regularly publish our findings in popular articles like Good Fruit Grower, American Fruit Grower, and universities' Extension web pages. The implementation phases of the program will conduct the evaluation. Evaluation objectives are as follows.

- Determine the extent to which the AWM platform assists growers in making informed decisions about tree removal rates based on economic and ecological factors.
- Assess the platform's usability, including ease of navigation, inputting data, and understanding recommendations.
- Measure participants' commitment to the AWM program and the impact of shared commitment on program effectiveness.

- Evaluate the economic and ecological impact of AWM at the farm level.

5 Conclusion

We present the proposal for an Extension program that uses a decision aid tool for AWM of WXD. The program is developed using a logic model and presents an economic analysis of WXD management at farm and landscape levels. The logic model not only helps to systematically outline the target audience's challenges and opportunities and design activities according to these challenges and opportunities but also plays an important role in defining measurable outcome goals. This approach ensures the effective dissemination of information on the costs and economic benefits of WXD management. Additionally, the availability of in-person, online, and hybrid Extension activities increases outreach and engagement with the audience.

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Acknowledgments: We thank Dr. Scott Harper for providing invaluable comments. Also, we thank the 2024 AAEA Extension section committee, participants, and judges for their insightful feedback. This commentary is based on the material submitted to the 2024 AAEA graduate Extension competition. A copy of the original proposal and presentation slides are available as supplementary materials to this paper. This material was made possible, in part, by a cooperative agreement from the USDA APHIS. It may not necessarily express APHIS's views.

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