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Long-term Citizen Science Project Led to Pinot noir Yield Management Changes

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Abstract

Background and goals

In premium Pinot noir production, there is an assumption that lower yields achieved through cluster thinning result in higher quality fruit. To challenge this idea within the Willamette Valley, a decade-long industry citizen science project was conducted.

Methods and key findings

The project, referred to as the Statewide Crop Load Project, used qualitative analysis methods to evaluate industry participant observations, changes in practice, and economic impacts. Adoption of new practices took time; however, fruit quality, vine health, and wine sensory observations facilitated the increase in company-wide target yields. Economic impacts reported by participants included reduced thinning costs and increased quantity of fruit at desired quality.

Conclusions and significance

Participants increased target yields after participating in yield management research as industry citizen scientists. They reported positive economic impacts associated with those changes. The effectiveness of participatory research helped redefine the yield-quality relationship for premium Pinot noir production within companies and the larger industry.

Key words: adoption, citizen science, crop load, impact, participatory research, yield

Introduction

An assumption in the premium wine industry is that low vineyard yield, commonly achieved by cluster thinning to target yields, is better for grape and wine quality. Due to Oregon's cool climate and short growing seasons, growers often employ cluster thinning in late summer in an attempt to improve fruit and wine quality (Uzes and Skinkis 2016). In most cases, cluster thinning is used in vineyards growing Pinot noir grapes that will be used to produce premium wines. Pinot noir accounts for 59% of planted winegrape acreage in Oregon and is a primary cultivar of importance in the Willamette Valley, the state's largest grape production region (University of Oregon 2024).

Although cluster thinning in premium winegrape production is common (particularly in cool climates), it can be overdone (Mawdsley et al. 2019), leading to low yields and decreased profitability. Cool climate research in red wine grape cultivars reveals that seasonal differences have more influence on berry composition, fruit quality, and wine sensory than vineyard canopy management practices, including cluster thinning, shoot thinning, or cluster zone leaf pulling (Bowen et al. 2011, Preszler et al. 2013, Frioni et al. 2017, Reeve et al. 2018). Similarly, research in an arid, warm climate found that differences were related to weather and soil moisture, not yield (Keller et al. 2005). Other crop management studies have questioned the need to cluster thin to lower yields in favor of practices such as cluster zone leaf removal (Smith and Centinari 2019), or suggest that cluster thinning should be done in conjunction with cluster zone leafing and shoot thinning (Geller and Kurtural 2013). Additionally, different cluster thinning trials show inconsistent results and no clear positive impact on fruit and wine quality (King et al. 2012, Gil et al. 2013, Condurso et al. 2016, Yuan 2016).

Other work has provided growers with decision-making tools to optimize the economics of cluster thinning and assess financial feasibility of low yields (Preszler et al. 2010). However, there is a lack of defined guidelines on target yields to achieve desired quality. Yield management studies have been carried out for different winegrape cultivars and climates but are often conducted for 2 to 3 yr and at a limited number of sites (Geller and Kurtural 2013, Frioni et al. 2017, Reeve et al. 2016, 2018, Mawdsley et al. 2019). Longer-term studies

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are necessary to assess yield-quality impacts across more growing seasons, particularly because the impact of seasonal weather on fruit quality is greater than that of vineyard management practices. Given the lack of solid, science-based yield-quality guidelines, it is hard to encourage producers to change target yields.

Conducting longer-term studies that engage producers offers an opportunity to evaluate yield-quality impacts (Skinkis 2019). Participatory research in agriculture is becoming more common and can be beneficial when incorporated alongside conventional research, allowing growers to observe on-farm results and widening the research scope. However, industry involvement must be integrated into research projects with careful consideration of timing, level of involvement, and variability among participants and agricultural systems (Neef and Neubert 2011). Most participatory research in the United States focuses primarily on pest and nutrient management (Delate et al. 2017). The winegrape industry has been involved in general farming and business operation participatory research, ranging from sustainability (Hillis et al. 2018, Masson et al. 2021) to environmental and human health concerns (Perrin et al. 2022, Madouas et al. 2023) and climate change (Naulleau et al. 2022). However, participatory research on specific viticulture practices that can have major impacts on farm environmental and financial sustainability is lacking on a national scale. Additionally, many participatory studies are short term (Jaramillo Diaz et al. 2022), making it difficult to determine the long-term impact, especially when farming is affected by growing season weather conditions that vary year to year (Togbé et al. 2015). Lack of long-term information on new or different practices can result in hesitancy among growers and prevent complete adoption of a practice (Perez et al. 2023).

Changes can take time to become accepted as standard practice, especially in high value crops such as winegrapes (Uzes and Skinkis 2016). Although long-term grower or industry impact and change are difficult to quantify, participation is the first step in the process to adopt new practices (Aare et al. 2021). Growers have occasionally conducted experiments and viticulture trials themselves, but obstacles limiting their experimentation and the quality of data reduced their likelihood of continuation (Song et al. 2022). A long-term participatory research project spanning 9 yr and three countries found that involving growers during the study resulted in implementation of more sustainable viticulture practices (Madouas et al. 2023), although lack of time can be a barrier to grower participation (Delate et al. 2017).

When recruiting for participatory research, it is important that volunteers serving as participants are interested, engaged, and invested in the study (Jaramillo Diaz et al. 2022), as motivation for involvement and engagement can change over the duration of a research project, especially in longer-term studies (Larson et al. 2020). Research coordinators should consider that participant age can influence adoption rates and willingness to learn new practices (Larson et al. 2020, McCoy et al. 2023), and should ensure that participants achieve the desired learning outcomes, a component that can easily be neglected (Druschke and Seltzer 2012). Ultimately, it is crucial that citizen science projects include industry participation, especially when the research challenges tradition or status quo (Skinkis 2019, Aare et al. 2021, Parks et al. 2021).

Surveys and interviews are often used to quantify stakeholder adoption from participatory research studies (Togbé et al. 2015, Hillis et al. 2018, Parks et al. 2021, Song et al. 2022). Surveys are convenient and efficient, especially with online tools and access widely available in the U.S. However, survey response rates are typically low, ranging from 5% to 35% (Pennings et al. 2002, Vaske 2008, Larson et al. 2020). Adoption and decision-making research in extension viticulture uses small sample sizes by necessity; however, the work can still provide helpful information for grower decision making and extension personnel program development (McCoy et al. 2023). Interviews are more time consuming to conduct and have less reach, but they are an effective tool to extract more in-depth information than a survey.

Growers learn from colleagues and are more amenable to adopting change when they can conduct their own trials (Song et al. 2022). However, recognizing that grower-initiated and grower-led projects often flounder, leadership was provided to the Oregon industry in tackling a large production issue that limited profitability—cluster thinning to achieve low yields. A 10-yr yield management project known as the Statewide Crop Load Project was led by Oregon State University (OSU) and involved members of the commercial winegrape industry as citizen scientists. A citizen scientist is defined as "a member of the general public who engages in scientific work, often in collaboration with or under the direction of professional scientists and scientific institutions" (OED 2014, Vohland et al. 2021, Vlaminck et al. 2024). Results from the project countered conventional wisdom in the yield-quality paradigm and led to an increase in state-reported yields (Skinkis 2019). To quantify the outcomes of this long-term research, impact evaluations were conducted for individuals and companies involved in the project. We hypothesized that those individuals and companies most engaged in the research would increase target yields and realize positive economic impact on production.

Materials and Methods

From 2012 to 2021, OSU Viticulture Extension led a university-industry collaborative yield management trial known as the Statewide Crop Load Project. This project was open to any commercial vineyard and winery that was willing and able to conduct a cluster-thinning trial for a minimum of 3 yr in their vineyards and process the resulting trial fruit into wines for sensory evaluation. Growers were to implement two or more cluster-thinning treatments in their vineyards in a randomized complete block

design, with at least three replicates. The OSU research team provided training and protocols for the project. All field- and winery-based data were collected by producers and reported to OSU, except for fruit chemical analyses, which were done by either OSU or ETS Labs. Data were collected and analyzed by OSU and annually shared with industry participants in the form of a participant team meeting and reports. Impact evaluation of the participants was conducted at two points during the project: first in 2017 to 2018 for midproject results, and then for postproject completion in 2024.

Midterm surveys and interviews

Data were gathered from project participants in 2017, 5 yr into the project. A 19-question survey was developed to understand participant involvement, observations from the vineyard and/or winery, interpretations of the vineyard/wine data, whether any changes had been implemented because of project participation, and benefits of joining the project (Supplemental Questionnaire 1). Questions also included demographic information such as the company, individuals' position within the company, and involvement costs such as human resources and time. All collaborating companies, both current and past, were invited to participate by completing the survey online using Qualtrics. Recruitment emails were sent to two to four members of each company, including vineyard managers, viticulturists, winemakers, enologists, or business owners (n = 31). Information about the study was provided to participants in an informed consent statement at the beginning of the questionnaire, following OSU's Institutional Review Board policies. The questionnaire took ~20 to 30 min to complete, and participants were given 90 days to complete the survey (March 2017 to June 2017). Multiple responses per company were received, totaling 28 participants with an average completion rate of 94%; a few respondents (n = 4) did not fully complete the survey.

Interviews were conducted within 1 yr following the participant surveys to obtain more detailed information on the company production goals, operational management, yield management practices, and how those yield management practices were affected by project observations (Supplemental Questionnaire 2). The delay in timing was to ensure adequate participation at a time that conflicted the least with crop production and wine sales cycles. Not all companies were subject to the interview, as effort was placed on the 10 companies most involved and currently engaged in the project. Interviews were semi-structured phone interviews with individuals or groups, depending on the size of the company and the teams involved in the project, and were conducted over 1.5 mo in spring 2018 (April to May) by a faculty research assistant who took detailed notes. Interviews ranged from one to four individuals participating per session, but most (70%) were with two company staff members at a time. Interviewees consisted of vineyard managers, owners, winemakers, viticulturists, and winery staff. Verbal consent was given, and interviews lasted ~45 min.

Postproject focus group meetings

To quantify impact at the end of the project, focus group meetings were held 2 yr after field project completion. This allowed participants time to produce wines from the 2021 vintage (the last year of the field trial), age and evaluate those wines, reflect on the prior seasons and vintages, and apply the knowledge gained to their operations. Fourteen focus group meetings were held from February to April 2024. Individual meetings were held with each company that participated fully in the project (3 or more years). Each meeting was 2 hr long and held at the participants' chosen location, often at the company offices. The meetings were open to other company staff who were part of the project or were important to quantifying the impact on the company's production.

The meetings began with a multiyear summary of research results from the company's field trial during the first hour of the meeting, presented by the project principal investigator (PI) (Skinkis). The PI and graduate student (Osterman) or another Skinkis Lab staff member present for notetaking noted primary observations and discussion about the results. The second half of the meeting focused on discussions of impact and practice change. This was structured as an open discussion guided by a standard question set asked at each meeting. Questions aimed at understanding changes in practice, financial and economic implications, and scope of project information sharing by participants (Supplemental Questionnaire 3).

Data analysis

Survey data were analyzed and coded to identify recurring themes and trends among participant responses. Open-ended questions were thematically coded to identify and organize main topics in responses. Open-ended questions could have multiple themes in one response and therefore could be counted in the analysis process more than once. Counts and percents were calculated for each question for better understanding and to view the spread of responses.

Notes written during the midterm interviews were transcribed and care was taken not to misconstrue quotes or deviate from the intended meaning, as interviews were not recorded. Responses were categorized based on the various themes present in responses. Overarching themes such as demographics, expectations, outcomes, project experience, and wine information were further dissected and quantified using the detailed transcripts from each interview. The same faculty research assistant who conducted the midterm interviews analyzed and coded both the midterm survey and interview data. This allowed for uniformity and consistency in the analysis process.

Focus group meeting notes taken by both the PI and graduate student were cross-referenced and uploaded to Quirkos for qualitative analysis. Participant data were then categorized based on themes from the discussions and quantified. Quantifying data involved using coding to produce counts for various themes, ideas, and responses to questions asked in the discussions.

Descriptive statistics were used to summarize the data from surveys, interviews, and focus group meetings. A database of participant history and involvement was maintained by the PI and used for a network analysis of participant involvement. This database was created using contact lists provided by companies participating in the project from 2012 to 2021. The level of involvement was quantified using a five-point scale based on each individual's role in the project and position in the company (Table 1). The connectivity and associations of participants were visualized using Flourish (Canva).

Results and Discussion

Participant demographics

A total of 25 companies participated in the project, 15 of which fully participated for the minimum of 3 yr. Four companies (five vineyards) were involved in the project for the maximum of 10 yr. Most companies established the trial in one block; however, three companies chose to conduct trials in two different vineyards that they owned or managed, totaling 18 vineyard sites involved in this analysis. All vineyards of fully participating companies were in the Willamette Valley region, including seven American Viticultural Areas (Figure 1). The majority of participants were estate vineyards and wineries (73%), and all other participants identified as contract growers.

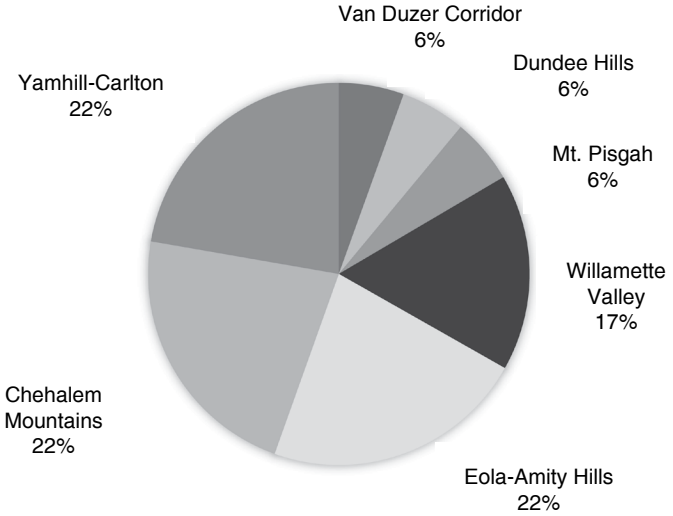

Figure 1 Distribution of Statewide Crop Load Project vineyard locations by American Viticultural Area within Oregon's Willamette Valley.

Midterm survey

The survey response rate was 93% by company and 77% by individuals. Some individuals from the same company completed the survey together; this was counted as a complete response for both individuals. The greatest number of participants considered themselves highly involved in the project (Figure 2). Participants mainly identified as being responsible for communicating protocols and information from the project to their company (Figure 3).

At this point in the project, participants received research reports showing results from vineyard, fruit, and wine sensory data based on each company/vineyard and season/vintage. Vineyard data showed little impact of cluster thinning on fruit ripeness at harvest, and when there were differences, they were inconsistent across vintages. Furthermore, there were no differences in vine growth data. Winemaker sensory panels led by OSU analyzed the wines from each company and vintage, and there were no differences in wine sensory perception based on cluster thinning. Participants learned of these results from the annual meetings and reports provided to them and in summary presentations given to industry at large.

Input from participants regarding observations in their project vineyards and wines was also requested for the surveys. Participants reported no observed difference in vine health between crop levels (Table 2), which aligns with the project field data and other cool climate studies reporting limited-to-no impact of cluster thinning on vine growth (Preszler et al. 2013, Frioni et al. 2017, Mawdsley et al. 2019). Many (60%) responses indicated fruit composition effects

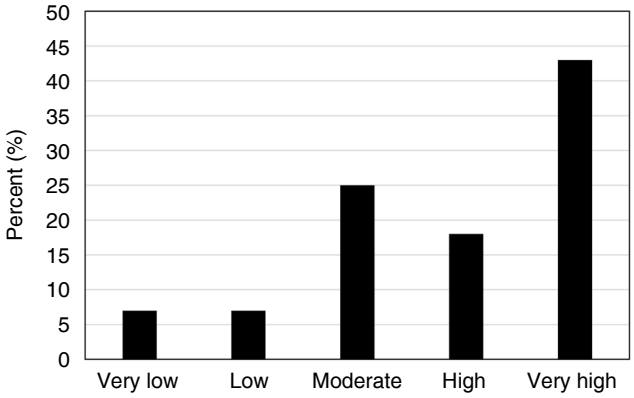

Figure 2 Participant-reported level of involvement in the midterm survey of the Statewide Crop Load Project.

Table 1 Five-point scale using individuals' position within the company, and role in the Statewide Crop Load Project, to rank level of involvement for network map visualization.

Rank	Company position and project role
1	Did not participate actively, could not/did not make decisions
2	Collected data but did not have background knowledge (intern/viticulture technician)
3	Agreed to project participation and observed results only, read reports (owner)
4	Processed data (made wines, ran sensory, project setup, attended meetings, etc.)
5	Heavily involved in the project, made decisions for the company (engaged owner)

such as slower total soluble solids (TSS) accumulation and lower TSS and higher acids in higher crop yield treatments at harvest, suggesting slower ripening, among other fruit composition observations (Table 2). However, these statements were made based on either visual observations or preconceived notions, as ripening curve data were part of the data collection protocols but were not completed by most participants because of limited time and resources leading up to harvest.

Only 52% of survey participants provided wine observation responses. Of those who responded, there was no consensus on wine composition and sensory impacts due to cluster thinning practices, with some participants preferring the lower crop wines over the high crop wines, and vice-versa. The highest percentage of responses (41%) reported little-to-no difference in wines from the trial (Table 2). These observations match field-based research in the region, where cluster thinning Pinot noir had little effect on vegetative growth but increased TSS and pH in high yield years (Reeve et al. 2016) and had variable impact on wine sensory perception (Reeve et al. 2018).

Given the lack of clear differences in fruit and wine quality with cluster thinning, many participants (48%) were beginning to change their perceptions of crop level in relation to fruit quality, namely, that higher yields would not reduce fruit or wine quality. The majority of participants shared project information internally within their company, while only half shared their experiences and information from the project with industry colleagues beyond the company (Table 3). At this point in the project, participants were still in the learning phase and not yet comfortable with making substantial changes on a company scale.

Participants in vineyard positions (e.g., viticulturist, vineyard manager) thought the higher crop levels were more economical (75%), mentioning both reduced thinning costs and the increased quantity of fruit to sell as potential financial benefits. However, only 38% of winemaking participants believed that higher yields were more economical, acknowledging a reduction in the costs of goods sold, but still maintaining concern about wine quality. The divide of perceived economic impact between vineyard managers and winemakers was anticipated (Keller et al. 2008, Somogyi et al. 2010). However, both parties were speaking from perception alone. At this point in the study, producers had not changed their practices to a larger scale to quantify the direct impacts of cluster thinning or changed wine quality at the company-wide level. Cluster thinning comes at a significant cost, requiring ~100 hr/ha (Olen and Skinkis 2018), and lower financial returns are expected on thinned blocks (Preszler et al. 2013).

Understanding the motivations for citizen science research is necessary to optimize project outcomes for both the researcher and the participant. Participants considered that the general knowledge and understanding gained from their participation was a benefit of their involvement in the project. Many participants also valued collaboration with university and industry colleagues. The most challenging aspect of project participation was the labor required. Factors such as time, labor, and proposed methodology can limit experimentation and be perceived as obstacles to involvement (Song et al. 2022).

Midterm interviews

More detailed information from participants regarding adoption was collected during the midterm interviews. At this point, 40% of participants increased target yields by 26%. The majority of participants (90%) found it difficult to visually distinguish cluster thinning treatments in the vineyard based on plant growth response. Regarding wine sensory perception, 60% of participants could distinguish differences between wines based on cluster thinning levels; lower crop level wines (more cluster thinning) were not perceived as better than the rest. All participants believed that target yields should be evaluated each season, rather than relying on the same targets (e.g., tons/acre or tons/ha) every year. Respondents from eight of the 10 companies interviewed believed that hanging more fruit (higher yield) in warmer years could be a benefit to preserve acidity, while higher crop yield would limit ripening in cooler years. However, these responses reflected expected response rather than data in-hand because project data did not support the hypothesis that higher yields lead to consistent differences in TSS, pH, or titratable acidity. Indeed, studies have shown cluster thinning to improve ripeness in

Table 2 Midterm participant survey responses to open-ended questions on vineyard, fruit composition, and wine quality observations while participating in the Statewide Crop Load Project.

Observation level	Response	Percentage of responses[a]
Vineyard	No difference in vine health	83
	Unsure of vine health differences	17
Fruit	Lower crop ripens earlier	56
	No difference in fruit composition	40
	Vintage dependent	28
	Low crop - better flavor	20
	High crop - more balanced	8
Wine	Little or no difference	41
	Unknown effects	29
	Low crop preferred/ higher quality	35
	High crop preferred/ higher quality/more complex	24

[a]Responses were subject to thematic analyses and percentages of responses are shown based on how often each theme was mentioned relative to all responses received. Not all respondents provided responses; observations were reported by 70, 76, and 52% of respondents for vineyard, fruit, and wine observations, respectively.

cooler years of cool climate regions (Frioni et al. 2017), especially with high crop yields. In fact, many participants expressed desire for cooler seasons in project years to test this hypothesis further.

Participants described changes to cluster thinning methodology that were adopted outside of the project. Many participants (77%) continued to use common industry descriptors for their thinning methodology, including a "green pass" to remove lagging green clusters (done after veraison), removal of secondary cluster branches known as "wings," the removal of "thirds" (the distal third cluster per shoot), removal of "raisins" (shriveled clusters), and removal of clusters forming on lateral shoots, known as "second crop". In most cases, thinning was conducted over one to two manual labor passes—what growers described as "clean up" thinning methods, rather than thinning a specific number of clusters per shoot.

Half of the participants at this stage of the project believed that reduced thinning passes should save money, while 60% cited increased harvest costs as a concern with increased yields. Often there are economic constraints to adopting new practices (Jaramillo Diaz et al. 2022), and limited winery space and sales capacity were often cited as obstacles to adopting higher yields. After project results were communicated, 80% of participants believed higher yields would not affect quality, yet changes had not been made at the company level. Other work has shown that participatory research increases understanding of the subject matter, even when long-term changes are undetermined (Jaramillo Diaz et al. 2022). Additionally, increased knowledge from participatory research does not always result in the adoption of new practices, but makes the preexisting practice more informed (Togbé et al. 2015).

The majority of participants (80%) wanted to share the knowledge they gained with industry colleagues. Participants believed they had credible information, as they observed results firsthand and were guided by a university research team. Other research suggests that communication between growers can be a source of trustworthy information and is important for adoption of practices (Parks et al. 2021). All participants reported that they wanted empirical data to help address the yield/quality relationship, and the majority (90%) reported enjoying research and experimentation. Similarly, Larson et al. (2020) found that science-related contributions were a primary motivation for citizen scientists participating in long-term research that led to continued engagement. Several growers had conducted unofficial experiments on their own prior to involvement in the Statewide Crop Load Project. Growers often conduct experiments to learn about practices, gain knowledge, and solve problems (Song et al. 2022). Most participants saw the value in contributing to, and participating in, research as industry members. They considered involvement to be worthwhile yet challenging, especially around harvest, and believed participation improved their management and knowledge of their vineyards.

Postproject focus group meetings

Of the companies that participated fully, 93% attended the postproject focus group meetings. The number of people in attendance ranged from two to six individuals per company, with upper management present for most companies. As reported previously, on-site experimentation and observation are often followed by greater rates of adoption (Parks et al. 2021), and all companies made yield changes as a result of participating in the project. Of those companies present in the meetings that reported their yield changes (61%), the average target yield increase was 39% (Figure 4). One participant (contract grower) reported decreasing target yields by 25%, because of what they learned and observed during the project. This participant had target yields set too high, as spacing and climate limited what their vineyards could feasibly produce. Most participants (85%) also reported observing higher target yields statewide and throughout the broader industry, indicating that information spread and practice adoption was happening industry-wide.

The majority of participants (77%) changed thinning practices over the course of project participation, ranging from reducing the number of passes per season to adjusting thinning methodology. Many participants (46%) reported adopting a more descriptive and visual regimen when thinning, looking for balance and uniformity. Most participants (62%) mentioned the importance of managing for vine balance rather than for target yields. Additionally, participants began

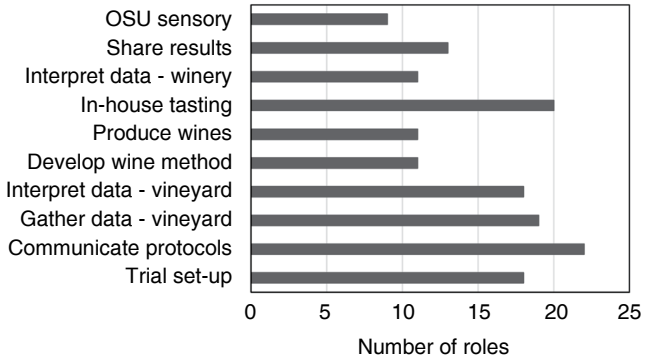

Figure 3 Number of roles held by participants in the Statewide Crop Load Project, as reported in midterm survey. OSU, Oregon State University.

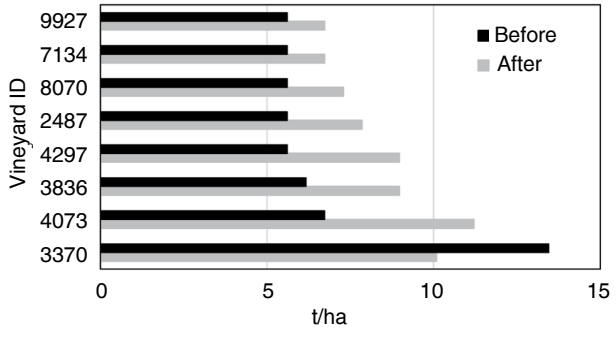

Figure 4 Vineyard target yields (reported in metric tons/ha), both before and after project participation, as reported in the postproject focus group meetings.

to use weight per row length-based metrics (lbs/linear ft) rather than weight per area (tons/acre [tons/ha]) when describing yields. The weight per row length metric became more common in participants' vocabulary, throughout the company, and with clients. This change reflects an important shift toward a more appropriate evaluation of vineyard practices on a linear row basis rather than by weight per unit area (e.g., tons/acre [tons/ha]), the latter of which is more common in industry. This shift allows growers to more intelligibly evaluate yield potential and vine balance across vineyard locations with varying planting densities and avoid misinterpretation of what tonnage represents, a founded concept for quality winegrape production (Intrieri and Filippetti 2000).

Adopting new practices and implementing new knowledge can take time. One participant reported making company-wide changes after 1 yr of project involvement, while others reported yield increases for Pinot noir 7 yr after leaving the study. Participants indicated their future plans to adjust other factors that affect yield, such as vine spacing, trellis system, pruning practices, and rootstocks, when designing new vineyards based on new target yields and the knowledge gained through project participation.

Most participants (85%) referenced the importance of vineyard site (e.g., soils, topography, elevation) in winegrape production and its role in the variability of project results. For this reason, it was important for growers to carry out this research in their own vineyards to see impact. This is why some participants chose to use two blocks for the project. Most participants (69%) acknowledged the impact of vintage variation on fruit and wine quality, often associating wine sensory differences to the given vintage or to influences from the winemaking (i.e., wine style), rather than to the crop thinning treatments or yield. Although the results reported by the industry were based on their observations, regional research beyond the Statewide Crop Load Project reported similar seasonal/vintage variations in yield that resulted in varying berry composition and wine sensory results (Yuan 2016, Reeve et al. 2018).

All participants reported improved profits with yield changes. This was achieved in part through reduced thinning costs that were reported by 62% of participants. Only after observing the impact on their fruit, wine, and vineyards could companies begin to implement changes across more acreage. This change occurred at varying times for participants. Midterm survey results show that while participants saw the value in participation and potential benefits from higher yields, company-wide changes were not yet made. Slight yield increases were reported in midterm interviews compared to the survey, however, the most significant increase and impact were described during postproject focus group meetings. This difference may be attributed to the greater presence at focus group meetings of upper management personnel, who had insight into the financial ramifications. Factors such as increasing costs to farm and new management helped motivate these changes and the adoption of new target yields.

We interpreted these positive relationships between participation and adoption of new practices to be due to benefits outweighing the costs of the practice. Adoption of new practices must be financially sound to be implemented and last within a company (Hillis et al. 2018). This goal requires viticulture and enology staff to be involved in the research and share results with owners and upper management. Winery staff and owners often play a significant role in crop management decision making and setting target yields (Uzes and Skinkis 2016). Conversely, contract growers have limitations on what changes can be made on-farm and must comply with buyer demands. Contract growers in the project expressed a desire to share project information with other winemakers (the buyers) at a rate higher than that of estate vineyard participants. Most participants shared project information and experiences with other company staff as well as with industry colleagues. Contract grower participants had high rates of project communication throughout the project timeline. These growers also used project data and information in contract negotiations, fruit pricing, and client selection. For estate vineyard and winery participants, project information was increasingly shared externally as the project proceeded (Table 3). These sharing networks were important for practice changes, as growers with stronger social networks for sharing information were more likely to adopt changes in practice (Hillis et al. 2018).

Linking project participation, learning, and communicating outcomes are important considerations for quantifying impact. Keeping track of project participants was challenging over the course of a 10-yr project, given shifting personnel. A total of 86 individuals participated in the project. Of these, 13 moved to different companies during the project yet stayed involved, either by working for another company that was already participating in the project or by joining the project at their new location. Although the magnitude of information sharing is not quantified by project participant data, the data do reflect the spread of information beyond employment within a single company. Those who moved to different companies during the project held positions ranging from directors of viticulture and winemaking to interns and viticulture technicians. These participants were involved for an equally wide range of years (1 to 10) and were mostly involved in tasks related to data collection or data processing such as project setup, attending meetings, making wines, and running tasting panels at the winery.

The level of involvement between the participating individual and their company was quantified and is represented visually

Table 3 Rates of participant information sharing, by company type and assessment timing, in the Statewide Crop Load Project.

	Midterm survey		Postproject focus group	
Company type	**% Internal**	**% External**	**% Internal**	**% External**
Contract growers	100	66	75	75
Estate vineyard and winery	95	42	78	78

as a thinner or thicker line in the network analysis (Figure 5). The interconnective nature of the industry is shown in the network analysis, with more connections made between viticulture positions than between enology positions. Individuals in viticulture made up 77% of the connections between companies, while individuals in enology positions accounted for 23% of the connections. Understandably, owners were never linked to more than their own company in this analysis. However, certain companies had greater connectivity to other companies and individuals. The most connected companies were vineyard management companies that work with many client vineyards and wineries, and larger companies that purchase fruit from many vineyards. Two companies shared associations with the same three individuals, the most of any company. These companies were also among the three with two vineyards in the project and are considered large-scale producers. Smaller estate vineyards and wineries had fewer employees and less connectivity throughout the project. Producer size was found to affect adoption; due to time and resource limitations, smaller operations had a lower capacity than large-scale producers to adapt to changing circumstances (Babin et al. 2022). However, in this project, smaller companies adopted changes more readily, due to being fully integrated as an estate vineyard and winery.

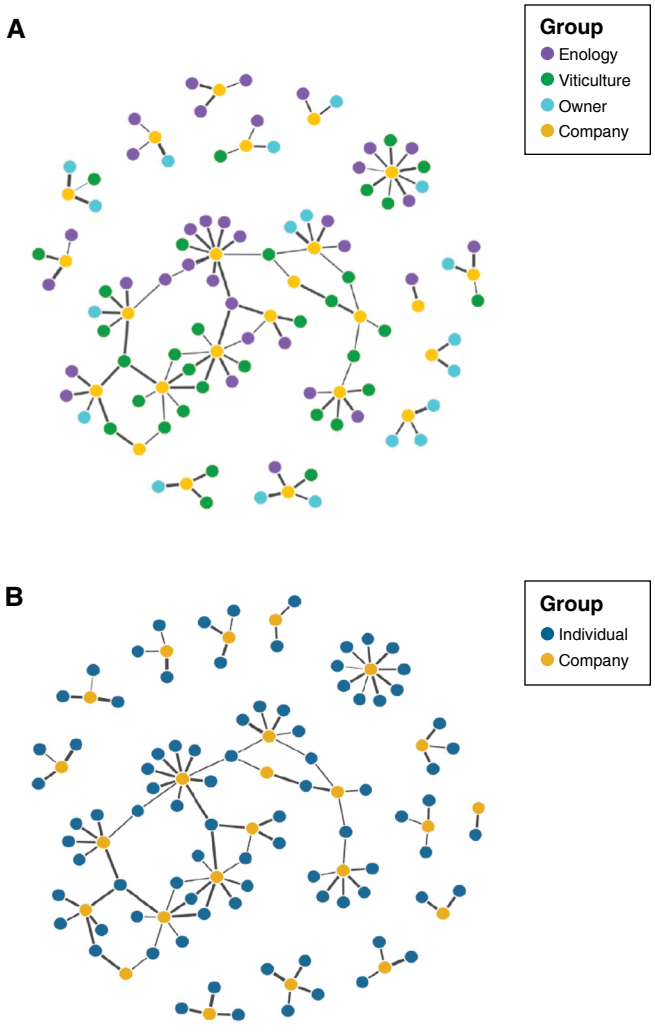

Figure 5 Network analysis of participants involved in the Statewide Crop Load Project and their associations and connections as **A**) the role of individuals within a company or **B**) companies as a whole, or individuals linked to that company no matter the role. Width of connecting line indicates level of involvement, with thicker lines corresponding to higher involvement.

Conclusion

This work demonstrates the successful involvement of industry members in on-farm and in-winery research that led to production changes at the producer and industry levels. The lack of negative impact of higher yields on vines, fruit composition, and wine quality helped facilitate the adoption of higher yields in premium Pinot noir production. The influences of vintage variation and location were emphasized and participants expressed willingness to carry more fruit (i.e., higher yields), especially in warmer years. In addition, the importance of managing for vine balance specific to the vineyard site, rather than to a universal yield standard, was highlighted.

Postproject focus group meetings revealed that participants increased target yields by 39% as a result of study participation. Changes in target yields took time to adopt, with participants making changes from 1 to 7 yr after project involvement; impact evaluations conducted throughout the project highlight the time required for the learning and adoption process when introducing new practices. Communication among industry members increased over time, and contract growers maintained high rates of information sharing throughout the course of the project. Reported economic benefits included reduced thinning costs and increased quantity of fruit that maintained desired quality. Future work to explore long-term adoption will be important in understanding the need for industry outreach from the project, repeated trials, or new trials that push the upper limits of Pinot noir yield not achieved by this study.

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Supplemental Data

The following supplemental materials are available for this article at ajevonline.org:

Supplemental Questionnaire 1 Midterm survey questions for Statewide Crop Load Project participants current and past, administered by online survey platform in 2017.

Supplemental Questionnaire 2 Questions used in phone interviews held during the midterm stage of the Statewide Crop Load Project in 2018.

Supplemental Questionnaire 3 Questions posed to companies at postproject focus group meetings in 2024.

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Data Availability

The data underlying this study are available on request from the corresponding author.

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