*Western SARE Competitive Grants: Graduate Student*

***Strategies to manage understories for ecological value in sustainable hazelnut orchards and matrix oak woodland habitat***

***Project Summary***

Most hazelnut farms use intensive spraying, scraping and flailing to control pests and maintain a bare orchard floor to facilitate harvest.  These practices lead to eroded orchard soils, loss of beneficial insects, and chemical health risks. Our overarching goal is to develop novel, sustainable strategies of understory management.

First, we will test whether pig grazing on can be used to reduce filbertworm pest loads in orchards and nearby native oak stands. We hypothesize that pigs will preferentially graze hazelnuts and acorns when available and by removing infected nuts, that grazing will reduce pest pressure.  We will install pig grazing plots in orchards and neighboring oak stands and monitor filbertworm populations.

Second, we will test whether native plants can serve as cover crops to promote beneficial insect diversity and improve soil health. We will establish cover plots with 18 native species in orchards that will be monitored for plant species success, beneficial insect diversity and various metrics of soil health.

Both of these strategies address critical production challenges while enhancing sustainable goals including adding diversified crop revenues, lowering infection rates, and promoting healthier orchard soils for healthier trees. The hazelnut boom also provides a unique opportunity to support rare oak-prairie habitat through incentivizing conservation of existing oaks, expanding native plant populations and supporting beneficial insects.

*Relevance to Sustainable Agriculture*

Hazelnuts are a booming industry in Oregon’s Willamette Valley, where 99% of the US crop is produced (Honea 2016; Perkowski 2017).Key challenges for hazelnut production are pests and the need for bare ground at harvest. Traditionally, farms have used intensive spraying, flailing, and scraping to eliminate pests and understory vegetation (Olsen 2013). These practices come at the cost of eroded orchard soils that don’t hold moisture, loss of beneficial insects, and farmer health risks from chemical exposure. Aware of these costs, farmers are increasingly interested in sustainable alternatives.

Our **overarching goal** is to develop novel, sustainable strategies of understory management for hazelnut farms. First, we will test whether pig grazing can be used to reduce pest loads while increasing economic stability. Second, we will test native plants as cover crops to promote beneficial insect diversity and improve soil health. Both of these strategies address critical production challenges while enhancing ecological goals. The hazelnut boom provides a unique opportunity to support oak-prairie habitat, a priority for the Oregon Department of Fish and Wildlife (2016)through incentivizing conservation of existing oaks, expanding native plant populations and supporting beneficial insects.

**Reducing pests**

The filbertworm (FBW), *Cydia latiferreana,* is a native moth that burrows into nuts and renders them inedible (Chambers 2011)**We propose using pig grazing as a sustainable form of physical pest control that removes nuts that harbor the immature FBW.** Pesticides are used in conventional agriculture to control FBW, while post-harvest nut removal is a more sustainable alternative (Hedstron 2014; Olsen 2002; Wiman 2018). Physical pest control has successfully been employed in other systems; for example, the use of chickens for blueberry pest management (Caruso 2014; Walters 2009). Because the larva burrows into nuts, removing them from the ground breaks the moth’s lifecycle and curtails it’s population size. This approach to FBW management can be effective at the local level but can be confounded by dynamics over the larger farm-wildland matrix. Specifically, the FBW native host is the Oregon white oak (*Quercus garryana*), a major component of important and endangered oak-prairie ecosystems of the Willamette Valley (Lewis 1992). Oaks near orchards serve as source pools of pests to re-invade hazelnuts. As a result, hazelnut growers may remove oaks from their lands (Larson *pers comm)* putting environmental and production incentives in conflict. This strategy is relevant to sustainable in that it adds a new revenue stream (pork), increases the saleable nut crop size, preserves native oak habitats, and reduces the exposure of farmers and farming communities to pesticides.

We will test whether pig grazing can reduce FBW pressure both directly (by grazing in a mature hazelnut orchard with known FBW levels) and indirectly (by grazing in an oak woodland understory). Pigs have a preference for acorns, and acorn-fed pig is an increasingly popular food type in the US (Rodriguez-Estevez et al. 2012; Shattuck 2013).

**Diverse orchard native plantings**

To harvest their crop, hazelnut farmers need clear, level ground. Traditional orchard floor management is unsustainable, with costs to soil health and to plant and animal communities, but cover crops can alleviate these costs (Mennan 2012; Olsen 2013). **We will test the use of native grassland plants as cover crops that promote** **beneficial species, including pollinators and pest predators.** If successful, this strategy will further align production and conservation goals by increasing the ecological value of hazelnut orchards. We will also evaluate whether native cover can match soil health benefits of conventional cover including stability, organic matter content, nitrogen and moisture (Creze 2017).

Hazelnuts have many pests, and biological control using predators is a common practice (AliNiazee 1998; Messing 1985; Walton 2009). Cover crops can support predator populations, including *Coccinellidae, Syrphidae,* and *Chrysopidae* larva, which rely on pollen and nectar as adults (Alcalá Herrera 2019; Messing 1983). They can also maintain prey populations to support predators when pest populations are low (El Haidari 1959). Increased plant diversity can also support diverse native pollinators, essential to the success of many crops grown near hazelnuts including blueberries, apples and marionberries (Klein 2012; Lundin 2017; Norfolk 2016; Saunders 1998). Like traditional cover crops, native plants can help to build and stabilize soils against erosion (Jiménez-Alfaro 2018). Native legumes including *Lotus* and *Lupinus* fix nitrogen like conventional vetches or clovers.

Using commercially available native grassland species, we aim to identify those that will thrive in hazelnut orchards. Native grassland plants are good candidate cover crops because they are quick to establish, small in stature and senesce by harvest (Frischie 2015). Structurally, orchards resemble the savannas where these natives found, improving the likelihood of success. For this strategy to work, species must create self-sustaining populations in the context of orchard management activities. **We will test the compatibility of selected prairie plants with flailing and scraping, and across orchards with different levels of canopy development.**

*Objectives*

**Objective 1: Reduce filbertworm pressure using pig grazing.** We predict that pigs will preferentially graze acorns and hazelnuts when available. AB, LH, LP and TL will collaboratively design and install pig grazing plots on My Brothers and Honor Earth Farms. TL will implement grazing treatments. AB and undergraduate assistant (UA) will measure rates of infected acorns (Fall 2020, 2021) and FBW densities both before and after pig grazing (Spring 2020-2022). Our hypothesis will be supported if grazing reduces the proportion of infested nuts and FBW populations in subsequent years.

**Objective 2: Promote beneficial plant and insect diversity through native cover cropping.**  We predict that robust native species will establish and persist in hazelnut orchards. AB and LH designed plots to be installed by AB and Marissa Lane-Massee (MLM) at Lane-Massee Farms in Fall 2020. We will compare the survival and reproduction of native species and traditional cover crops (Table 1). AB, MLM and UA will monitor plant species survival and insect diversity at peak flowering (Spring 2021, 2022). Our hypothesis will be supported if native plants survive, reproduce and elevate pollinator and predatory insect diversity.

**Objective 3: Ensure grazing and native cover does not compromise other sustainable goals.** We predict that pig grazing will not degrade vegetation in oak stands or disturb the orchard floor. AB and UA will establish vegetation and disturbance transects in Fall 2020 to be monitored immediately before and after pig grazing. We also predict that native cover crops will provide comparable or increased benefits over traditional cover crops in terms of soil moisture, erosion control nitrogen and organic matter. We will measure indicators of these soil conditions at peak flowering. Our hypotheses will be supported if there is no significant difference between treated and control plots in the understory and soil metrics described above.

*Research Materials and Methods*

**Objective 1: Reduce filbertworm pressure using pig grazing.**

We are testing this approach at two farms. My Brothers’ Farm is a 320-acre organic farm in Creswell, OR with over 2000 young hazelnut trees and several old oak stands. Here, we will test pigs’ ability to reduce pest pressure by grazing infected acorns in oak stands. A seed grant through the University of Oregon allowed us to collect baseline measurements and implement experimental treatments in summer 2018 and 2019. With Western SARE support, we will measure the FBW population’s response to grazing and expand our experiment Honor Earth Farm, an established 25-year-old orchard that has been monitored for FBW since 2018. Here, we will test whether direct orchard grazing reduces pest pressure.

In the summer of 2018, we established five-acre paired control and treatment plots in oak stands at My Brothers Farm and will do the same at Honor Earth in 2020. In one plot, we implemented a pig grazing program, while restricting grazing in the other. We used movable electric fences to implement the treatments, grazing each plot in four rotating pastures for a total of two weeks. Grazing (performed by 20 heritage pigs) was timed to correspond with initial acorn release (Sept-Oct) to target infected acorns as they are aborted and dropped early. We are using a Before-After Impact-Control (BACI) design to allow contrasts in our analysis in the same plot before and after treatment as well as contrasts between the grazed plots and paired control. We expect that grazing will effectively remove both infected and healthy acorns and hazelnuts and reduce infected totals in subsequent years.

To track success of this objective, we will sample nuts and count infected and healthy totals. At both farms we will randomly select five mature trees within each plot. Below each tree, we will clear vegetation from two 2m x 2m quadrats on opposite sides of the tree, spaced halfway between the trunk and the canopy drip line. Immediately before and after pig grazing in 2020 and 2021, we will count acorns and hazelnuts in each of these plots, checking for signs of FBW infestation (entry/exit holes). In the spring and summer following each grazing event, we will directly measure the effect of nut removal on FBW population density. We have constructed twenty 0.5 m x 0.5 m emergence traps: wooden frames covered in netting with a pheromone trap at the top of the top to lure and capture any emerging FBW moths. We will use 10 traps per plot and monitor them weekly during FBW emergence (May-July 2021-2022). We will also install four aerial pheromone traps per plot to measure moth densities over the summer. These methods have been previously successful in capturing moths and establishing initial densities. We expect that grazing will reduce FBW emergence and total FBW populations in subsequent years.

**Objective 2: Promote beneficial plant and insect diversity through native cover cropping.**

To test native cover viability and its effect on beneficial insect populations, we will establish native understory plantings at three orchards in the Willamette Valley managed by Lane-Massee Farms north of Salem, OR. We consider orchard age and management regime as factors affecting native species survival, respectively through light availability and disturbance intensity. The youngest orchard (15 years old) has a relatively open canopy, followed by the oldest (60 years old), and the intermediate orchard (40 years old) has a nearly closed canopy at full leaf. We expect native cover crop to grow, survive and reproduce at higher rates in more open canopy conditions.

Typical orchard floor management involves summer flailing (large-scale mowing and branch chipping) and fall scraping (mechanical soil leveling) to facilitate harvest. Our management treatments incrementally remove these interventions to test their effects on cover crop survival. Within each orchard, we have established six 6m x 18m blocks. Each block consists of three adjacent 6m x 6m management plots; “flail + scrape”, “flail”, “none”. We expect minor effects of flailing and scraping, as native forbs die or go dormant before these take place.

To test native species’ potential for use as cover crops, we will seed sixteen native and four conventional cover crop species in Fall 2020 (Table 1). These will be segregated into native annual, native perennial and conventional (annual) seed mixes and broadcast in three 2.5m x 2.5m subplots within each management plot. We will leave the fourth subplot unseeded as a control. All natives are commercially available and were selected because they are common, persist in natural grasslands, perform well in restorations, establish quickly and reproduce profusely. Selected species can tolerate from full sun to partial shade. We will seed each subplot will at 8g/m2, regardless of the number of species in the seed mix, and we will seed each species evenly by weight (i.e. 1g/m2 in annual and perennial mixes).

Table 1: Selected species, characteristics and seed mixes.

|  |  |  |  |
| --- | --- | --- | --- |
| Species | Native | Functional group | Seed Mix |
| Collomia grandiflora | Yes | Annual forb | Annuals |
| *Amzinckia menziesii* | Yes | Annual forb | Annuals |
| *Clarkia purpurea* | Yes | Annual forb | Annuals |
| *Epilobium densiflorum* | Yes | Annual forb | Annuals |
| *Gilia capitata* | Yes | Annual forb | Annuals |
| *Lotus purshianus* | Yes | Annual forb (legume) | Annuals |
| *Plectritis congesta* | Yes | Annual forb | Annuals |
| *Sanguisorba annua* | Yes | Annual forb | Annuals |
| *Achillea millefolium* | Yes | Perennial forb | Perennials |
| *Agoseris grandiflora* | Yes | Perennial forb | Perennials |
| *Lomatium nudicaule* | Yes | Perennial forb | Perennials |
| *Potentilla gracilis* | Yes | Perennial forb | Perennials |
| *Prunella vulgaris* | Yes | Perennial forb | Perennials |
| *Viola praemorsa* | Yes | Perennial forb | Perennials |
| *Geum macrophyllum* | Yes | Perennial forb | Perennials |
| *Eriophyllum lanatum* | Yes | Perennial forb | Perennials |
| Winter barley | No | Annual graminoid | Conventional |
| Common oats | No | Annual graminoid | Conventional |
| Common vetch | No | Annual forb (legume) | Conventional |
| Dutch white clover | No | Annual forb (legume) | Conventional |

To evaluate species success, we will estimate percent cover. We will monitor plots at peak flowering, which for these species coincides with peak biomass. We will sample across each subplot with two line-point intercept transects of twenty points each, crossing diagonally in the center of the plot. Each transect will be four meters long with measurements taken every 20cm. We will drop a 1m x 1/8” pin at each point and record each plant it touches. By comparing percent cover of each species with the initial amount of seed added in each mix, we will identify which species performed best in each context.Without adding seeds, we will repeat this process in 2022 to evaluate species’ ability to reproduce, resist invasion by weeds, and maintain a viable population over time. We expect native annuals will grow faster and equal conventional cover in year one, especially in open canopies irrespective of management treatment, but perennials will perform better in shadier, less-intensively managed plots.

We will measure beneficial insect diversity concurrently with line-point intercept monitoring at peak flowering in 2021. We will sample insects in subplots planted with different seed mixes. We will collect airborne specimens with insect nets and inspect vegetation and the ground litter layer for crawling insects. Two collectors will work per sub-plot for exactly five minutes to ensure even sampling effort. We will only collect between 12pm and 5pm with temperatures over 55 degrees Fahrenheit and winds below eight miles per hour. We will bring unidentified samples back to lab for further identification, and if necessary, send samples to be identified by expert taxonomists at OSU. Due to plant diversity, we expect to find the highest beneficial insect diversity in native annual subplots, followed by native perennials, conventional cover crops and finally unseeded controls.

**Objective 3: Ensure grazing and native cover does not compromise other sustainable goals.**

To increase overall farm sustainability, pig grazing and native cover cropping cannot compromise other metrics of sustainability. To examine potential tradeoffs we will monitor pig disturbance levels, and contrast how native cover crops, traditional cover crops and bare ground practices affect orchard soils.

To measure pig disturbance in both oaks and orchards, we will establish four 100m transects per plot in Fall 2020. Immediately before and after pig grazing, we will estimate percent cover of freshly disturbed bare ground, undisturbed bare ground, litter, herbaceous cover, and shrubs in 2m x 2m plots each twenty meters along these transects. Any oak seedlings will be flagged before grazing to quantify losses. For each freshly disturbed area, we will measure depth, diameter, distance to nearest tree and note if any tree roots have been exposed. We expect pigs will preferentially consume hazelnuts and acorns, with insignificant effects on pre-existing vegetation, including hazelnut trees.

Conventional cover crops are used to stabilize soils, build soil carbon and nitrogen, and increase soil moisture. We will monitor indicators of these benefits at the seeded sub-plot level to ensure that native plants do not compromise them. From line-point intercept monitoring, we will estimate percent bare ground, a proxy for erosion potential and soil stability. Concurrently with line-point intercept monitoring, we will collect aboveground biomass as an indicator of belowground biomass and carbon storage. We will clip all aboveground biomass in a predetermined 0.25m x 0.25m square in each subplot. We dry biomass in a 60\*C oven for 48 hours then weigh it. We will measure soil nitrogen directly by taking soil samples with a soil corer and performing controlled combustion with a CN elemental analyzer. Finally, we will monitor soil moisture by installing 1/8” by 6” stainless steel probes into each sub-plot in March 2021 and recording conductivity with a HydroSense II moisture meter every other week until June. This is the period during which soils go from field capacity to being very dry. We expect that diversity and niche complementarity will help our native seeding plots provide comparable or improved soil quality metrics to conventional cover crops, and especially over the unseeded control.

*Educational Outreach Plan*

Our educational outreach philosophy is based on the principles of “translational” science of collaborative project design with stakeholders (Hallett 2017). We have been working iteratively over two years with our producer-cooperators to define this project’s problems, questions and potential solutions. This engagement leads to relevant and directly applicable results, facilitating broader outreach as we answer questions that producers are interested in rather than providing external solutions. Our close working relationship with our producers uniquely positions us in local networks to disseminate our research through farmer field days. For example, producer-cooperator Taylor Larson is a local leader in the sustainable hazelnut farming community as vice president of the Oregon Organic Hazelnut Cooperative, director of the Coast Fork Willamette watershed council, and leader for the Rogue Farm Corps apprentice program. These hazelnut farmers, environmentally minded landowners and future farmers are already interested in sustainable agriculture and are prime candidates for our educational outreach efforts.

Field days will be focused during periods of engaging research activity on the farms. Annually, there are two highly active seasons: May/June, when soil moisture, plant and beneficial insect monitoring take place and September/October, when pig grazing and associated monitoring take place. We will host one field day corresponding to each of these time periods in both 2021 and 2022. In 2021 we will focus on our objectives and research process, and in 2022 we will focus on disseminating lessons learned.

In addition to educational outreach to practitioners, we will use our research as a model of translational science in undergraduate education. Through our collaboration with My Brothers Farm, we have already hosted class field trips and had three undergraduates develop research for honors theses associated with this project. With support from Western SARE, we will continue this work as our project expands in scope. We also collaborate with Dr. Betsey Miller, at Oregon State University, to develop our FBW monitoring methods. Dr. Miller will serve as a link to OSU students and researchers who may also be interested in this work.

To reach a broader public we will participate in conferences and reach out to media outlets for press. This project has already been picked up in media publications by the University of Oregon public relations, Hazelnuts.com, and Eugene, OR local public radio. We will submit abstracts for ecological conferences including the ESA meeting, Willamette Valley Habitat meeting, Society for Restoration Ecology Northwest Meeting, the National Conference on Ecosystem Restoration and the Cascade Prairie-Oak Partnership Conference. We will also participate in farming conferences such as the Oregon State University Small Farmers’ Conference, the Nut Growers’ Society Annual Winter Meeting and Summer Tour, and the North American Agroforestry Conference (see timeline for dates). We will coordinate outreach for our pollinator monitoring with Dr. Stephanie Frischie at the Xerces society.

*Scholarly Publications & Educational Materials*

We will publish all scientific results of this project in peer-reviewed scientific journals. We aim to publish three manuscripts. Our first publication will focus on using pig grazing to control filbertworm, demonstrating the effects that grazing has on infected acorns and hazelnuts as well as emerging and adult filbertworm populations. The second publication will focus on identifying which native species can survive as native cover crops across variable management regimes and canopy covers. Our last publication will focus on the comparative benefits of native cover crops compared to conventional cover crops and bare ground. This publication will focus on beneficial insect diversity, but also consider characteristics of soil health. To reach relevant audiences some of this work will be aimed at specialized journals (e.g., *Journal of Agroforestry Systems*, *Journal of Integrative Pest Management*) whereas others will target general applied audiences (e.g., *Restoration Ecology, Frontiers in Ecology and the Environment*).

We will also tailor each main finding to an educational outreach publication targeted at farmers. These include:

* Pacific Nut Producer (Malcom Media)
* Hazelnuts.com (Northwest Hazelnut Company)
* Oregon’s Bounty (Oregon Farm Bureau)
* OSU Extension Publications (Oregon State University)

For each of the conferences listed in the educational outreach plan, we will develop posters or oral presentations with slideshows. We will make these available at the Hallett Lab website: [www.halletlab.netlify.com](http://www.halletlab.netlify.com). We will make handouts for field days based on these posters, consisting of a general project overview (cover crop or pig grazing depending on the season), simple results, benefits to producers and contact information.

*Evaluation of Producer Adoption (300 words)*

Changes in producers’ knowledge, awareness and attitudes will be primarily evaluated by reviewing Western SARE surveys provided at field days. Longer term indicators of producer adoption will include broader incorporation of sustainable practices to hazelnut farming in the Willamette Valley. We plan to develop a native hazelnut understory seed mix with Heritage Seedlings, the largest local supplier of native seeds for restoration projects in the Willamette Valley. This would parallel a partnership in California between academia, the Xerces society and Hedgerow Farms to develop an annual wildflower seed mix to be used in almond orchards. Sales of this seed mix will be a useful indicator of producer implementation of native cover cropping.

*Innovations and Contributions to Sustainable Agriculture*

This project has the potential to increase hazelnut farm sustainability by supporting local and regional ecosystems while providing benefits to farmers and farm communities.

Farm productivity will be increased through reduced pest pressure, increased nut yields, and increased usable land. If pig grazing reduces FBW population sizes, more healthy nuts can be sold. Currently, it is common to lose 10% of crops to FBW infestation. Native cover cropping can also reduce FBW and other pest populations by providing habitat and forage for predatory insects. If cover cropping increases soil moisture, less trees will be lost to drought stress, and the trees that survive will grow more quickly and produce more than if they had been stressed. Grazing pigs in oak woodlands expands the productive acreage of the farm. Finally, for multi-crop farms like My Brothers Farm, native pollinators can increase productivity of these crops.

Farm profits can benefit from increased productivity, but also through efficiencies and cost reduction. For example, nut removal reduces the need to spray (typically $200/acre/year). This can help reduce barriers to organic certification, which allows growers to increase revenues substantially (conventional = $2/lb, organic = 9$/lb). These prices are also more stable, as conventional hazelnuts are mostly sold overseas and affected by global politics. Some growers remove oak from their property to reduce FBW, a substantial cost that could be avoided through grazing. The main cost in raising pigs is feed, and by allowing pigs to graze for nuts and acorns, this can be greatly reduced. Finally, these sustainable practices provide a compelling story for farmers to engage customers with in selling their products.

Replacing a bare orchard floor with a diverse cover crop will help prevent erosion, a potentially expensive problem in hazelnut orchards. It will also increase soil carbon and help structure the soil, providing habitat for a diversity of soil organisms. Improved soil health benefits water quality as less eroded sediments finds their way into waterways. In addition, reduced pesticide and fertilizer use on farms also improves water quality.

A major innovation of this project is the alignment of production and conservation goals. Before widespread land conversion, much of the Willamette Valley was dominated by diverse oak-prairie. These have been reduced to less than 5% of their original extent, 80% of which are on private, and often agricultural, lands. Oak-prairie habitats are therefore among the most endangered ecosystems in the Pacific Northwest and working with farmers for their protection is essential for their conservation. Accordingly, the Oregon Department of Fish and Wildlife has recognized these as “priority” habitats for conservation and work is ongoing to restore and manage them (ODFW 2016). By increasing the ecological value of farms, sustainable hazelnut farming can play a role in supporting and preserving these systems. Expanding grasslands under hazelnuts and grazing in oak woodlands can help reduce the risk of local species extinctions by increasing connectivity and raising habitat value, leading to a closer integration of oak-prairie conservation efforts with sustainable agriculture.

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