# NRCS CONSERVATION INNOVATION GRANT
FINAL Report

**Grantee Name:** **Oregon State University**

**Project Title:** **New Opportunities for Establishing NRCS Pollinator Habitat in the Pacific Northwest**

**Agreement Number:** **NR203A750008G004**

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**Other Team Member:** **the Xerces Society for Invertebrate Conservation**

**Project End Date;** **4/15/2024**

**Project Summary**
The project addressed key challenges facing the adoption of NRCS practices promoting pollinator health in the Pacific Northwest (PNW Region), specifically in: 1) promoting pollinator habitat and pesticide stewardship in mid-Columbia sweet cherry orchards, 2) increasing the success of pollinator plantings in Willamette Valley hazelnut orchards by examining the compatibility of wildflower species to common pre-emergent herbicides and 3) increasing the nectar and pollen resources in non-irrigated pasture systems. The information from the project has reached over 1,000 producers in the region through field courses, lectures or trainings. The project has resulted in five guidance documents for growers and their advisors, as well as five peer-reviewed journal publications that have either been published or submitted.

Research conducted in mid-Columbia sweet cherry systems focused on planting for non-pollinator beneficial insects and on protecting bees from pesticide exposure. The study of non-pollinator beneficial insects resulted in a collection of over 15,000 specimens from across 20 sites in and around commercial orchards, including mature orchards, cover cropped areas prior to orchard establishment, sites that were not cover cropped prior to orchard establishment and oak white fragments bordering the orchards. Although analysis of our data will continue beyond the end of the project, preliminary analysis has demonstrated that: 1) beneficial insects are in highest density in white oak habitat but densities are dependent on the size of the habitat, 2) white oak fragments is not a source of key pests such as leafhoppers, but that densities are highest in orchard replanting areas not planted to cover crop and 3) cover crop hosted the highest number of native bees in the spring and spring blooming cover crops may be of greatest importance to beneficial wasps. Combined this data suggests that spring blooming cover cropping may help suppress leafhopper populations and white oak fragments may increase non-pollinator beneficial insects. We used this data to develop a guidance document for implanting practices that can improve oak habitat around sweet cherry orchards. Two years of sampling for pesticide residues

at commercial sweet cherry fields revealed 25 pesticide active ingredients in sweet cherry pollen, 11 ingredients from plants found in the understory of orchards and 28 ingredients found from plants growing in oak habitat. The prevalence of pesticide detection in plants growing in the orchard understory and in oak habitat suggests the need for pesticide stewardship practice that focus on drift mitigation, particularly for wild bees, which largely did not visit sweet cherry flowers.

Our research into the negative impact of pre-emergence herbicides in hazelnut systems took place across two commercial orchards and a research plot at Oregon State University. Analysis of data will continue past the end of the project, we found that flowering plant tolerance to herbicides was highly species-specific and varied by location, with better site preparation and more species-herbicide combinations resulting in successful crop establishment. Pre-emergent treatments were most effective in improving flowering plant establishment while also providing greater long-term weed control. Herbicide treatments also improved flowering plant establishment when species were seeded a year after treatment. Our work has resulted in planting recommendations based on the tolerances identified across our trials. The inconsistency observed in our results suggest that more testing could ensure species will establish when using herbicides, especially indaziflam.

Our final project explored the interaction between different pasture mixes (a mix dominated by legume species, a mix with heavy floral diversity and a simple grass-dominated mix) and closing dates to determine whether re-growth of nectar and pollen species could increase benefits to bees. We found the diverse mixtures had the highest dry matter for livestock, but lambs grew faster on legume-dominated pastures. Bloom density and bee visitation were 16 and 40 times greater with legume rather than simple pastures. Bloom density for diverse pastures was also relatively lower than for the legume pastures. The closing date treatments did not have any effect on the bee visitations for simple and diverse pastures, but bee visitations were higher with earlier closing (first) then mid (second) and late (third) closing for legume pastures. Our findings indicated that the diversification of pastures greatly increased pasture productivity, while legume pastures provided the highest bee benefit without penalizing lamb liveweight production in spring.

**Project Goal and Objectives:**
The project goal was to improve adopt rates of NRCS pollinator conservation practices in the Pacific Northwest (PNW) by better defining the benefits of practices associated with three key cropping systems in the region.

Objective 1: Better NRCS planting specifications for: (a) cover crop and conservation cover plantings adjacent to cherry orchards designed to help best prevent exposing pollinators and other beneficial insects to pesticides, and encouraging crop pollination and biocontrol and (b) targeting the pest management practices (595) which pose the highest risk to native bee communities.

Objective 2: Better NRCS planting specifications for summer blooming drought-resistant plants that are compatible with registered herbicides and that are designed to support honey bees, bumble bees, and other beneficial insects.

Objective 3: Project results will help improve the implementation of for forage and biomass plantings (512) and prescribed grazing (528) management plans that support livestock health, pasture productivity, and pollinator conservation.

**Project Background:**

The Pacific Northwest (PNW) has lagged behind the Northern Great Plains and other regions of the US in its pollinator conservation efforts. The lack of uptake of NRCS practices in the region is unfortunate, as the PNW has several characteristics which make it an ideal region to invest in pollinator habitat promotion. First, the PNW is one of the largest sources of honey bee colonies for California almond pollination, supplying growers across the Western US with bees for crop pollination. Second, most of the managed orchard bee (*Osmia lignaria*) are propagated in the PNW. Third, the native bee fauna of the PNW consists of almost 900 species, which is a fauna more diverse than that of all the states east of the Mississippi combined. Owing to high native bee species diversity and abundance, a number of crops in the region enjoy free pollination services. Finally, while the PNW is not home to any bee species listed under the federal Endangered Species Act, it is home to bumble bee species that have experienced significant range reductions.

Our project focused on removing barriers to adoption of existing NRCS pollinator-friendly conservation practices in the PNW. The project represents a wide spectrum of land management activities in the PNW (i.e., fruit and nut production and pasture management), and was unified through four key themes (Figure 1 ): (A) measuring economic benefits of practices associated with pollinator habitat (a Mid-Columbia fruit crop system and non-irrigated Western Oregon grazing system), (B) identifying forb, shrub and tree species that attract the widest spectrum of native bees and other beneficial insects, (C) improving implementation of existing conservation practices using selective herbicides and grazing that promote the establishment of target plant species and reduce the growth of weeds and (D) using conservation practices to preserve beneficial insects during periods of intensive pesticide use.

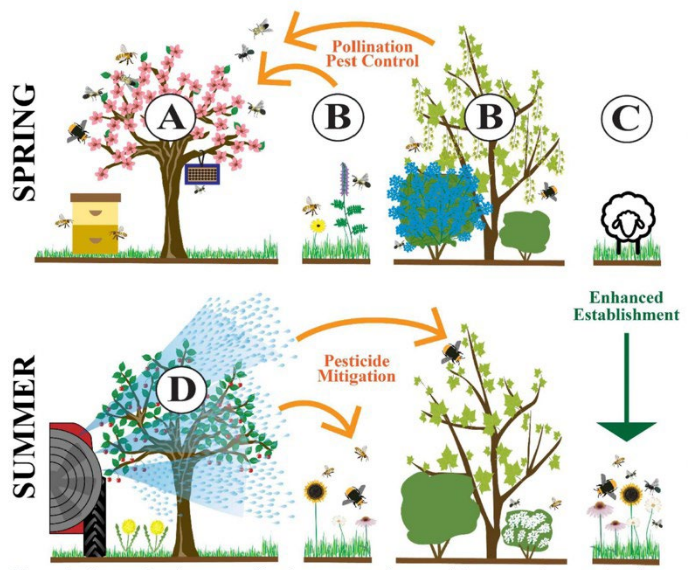


*Figure 1. Our project focuses on four key aspects of successful conservation practices for pollinators in the PNW. Specifically, the need to: (A) specify the economic benefits of pollination, natural pest control and livestock forage to producers, (B) identify plants, particularly ones that will bloom into summer, that serve a wide range of bees and beneficial insects, (C) improve implementation of practices by enhancing pollinator plant establishment by using selective herbicides and grazing and (D) determine if conservation practices conserve beneficial insect populations during periods of intensive pesticide use.*

**Project Methods:**

*Objective 1:* Beneficial invertebrates were sampled in 20 sweet cherry orchard and affiliated sites (4 blooming cover-cropped new orchard sites (primarily mustard and radish cover crop), 4 volunteer new orchard sites, 4 mature orchard sites, and 4 white oak fragments near orchards) once per month from April to August of 2021. Invertebrates were collected using a variety of techniques designed to assess aerial beneficial invertebrates such as flies and wasps (baited delta traps, and yellow sticky cards) and ground dwelling invertebrates, such as beetles and spiders (pitfall traps). Flowering ground cover plant communities and tree overstories were surveyed at each site.

Pesticide analysis was conducted from pollen samples trapped from commercial honey bee colonies contracted for sweet cherry in 2020 (n=12 orchards) and 2021 (n = 14 orchards). Pollen samples were sorted into uniform color groups and the species of plant they originated was determined with light microscopy. The location of these plants was confirmed using vegetation surveys. We then created a matrix of pesticide data associated with the pollen identity, the native and honey bees foraging on these floral resources, and the percent of the total sample each color group represents. We calculated the overall hazard of the pesticide of pollen from sweet cherries and pollen associated with plants in the understory and plants found in the white oak fragments surrounding the orchards. Finally, we collected bees within and surrounding all the orchards and associated them with the plant species they were visiting, allowing us to associated the hazards different bee taxa experienced across the landscape using a hazard quotient (HQ) which weights pesticide detections in pollen relative to the acute toxicity of the pesticides to bees.

*Objective 2:* Three two-year field studies were established in western Oregon between 2020 and 2021 to evaluate the response of ten wildflower species known to be attractive to bees to preemergence and postemergence herbicides. In October 2020, two studies were initiated in newly planted commercial hazelnut orchards. The first study was near McMinnville, OR, where the row middles were tilled and leveled after planting. The second site was located near Corvallis, OR, where the row middles of hazelnuts were not tilled. Ten wildflower species were seeded at recommended rates. The third study was initiated in September 2021 at the Oregon State University Lewis Brown Research farm in Corvallis, OR. The best six established pollinator species were selected for this study and seeded at double the rate used at the other locations. In the second year of the study, the 2021/2022 season, the six best established species from the previous season were reseeded on the same sites in McMinnville and Corvallis. The Lewis-Brown Horticultural Research Farm was reseeded in 2022. No herbicide treatments were applied in the second year, to permit evaluation of flowering plant establishment and weed control one year after herbicide treatment. Flowering plant tolerance was defined as treatments that did not reduce the biomass of a given species compared to the non-treated control.

*Objective 3:* The study was conducted at Oregon State University Farm in Corvallis, Oregon in 2021 and 2022. Pasture treatments were established in a 1.332-ha plot on October 1 in 2020. Prior to establishment, pasture paddocks were divided into four equal blocks to serve as replicates for the experiment. Each block was divided into 3 subplots, which were randomly allocated to a combination of (1) simple, (2) diverse and (3) legume pastures, giving a total 12 plots, each covering an area of 0.111 hectares (30 × 37 m.). Pastures were further divided into three equal subplots (12.3 x 30 m.) to apply rotational grazing. These subplots also served as different closing date (early, mid and late) treatments in both years. The productivity of the pastures to livestock was estimated by pasture dry matter (DM), lamb growth rates (LWG), preand post-grazing pasture mass, the botanical composition and nutritive value of pasture on offer, fecal egg counts, bloom density and bee visitation. Detailed methods are published in Claudillo et al. (2024, Agronomy: 14(1), 24).

**Project Results:**

*Objective 1 – Non-pollinator beneficial insect section:*

A key finding was that beneficial insects were associated oak fragments, rather than cover cropped areas or areas where replanted orchards were not planted to cover crops (volunteer). For example, among lacewings (Family Chrysopidae) that lacewing populations appeared first in oak fragments in April, before appearing in sweet cherry orchards in May (Figure 2). This finding suggests that oak fragments may provide spillover pest control services to orchards. Finally, we found that lacewings were more abundant, on average, in cover crops and "volunteer" sites later in the season (July and August) than they were in other site types, indicating that orchard associated sites may provide important habitat for lacewings later in the season. These results are preliminary, and we are still actively analyzing these data.

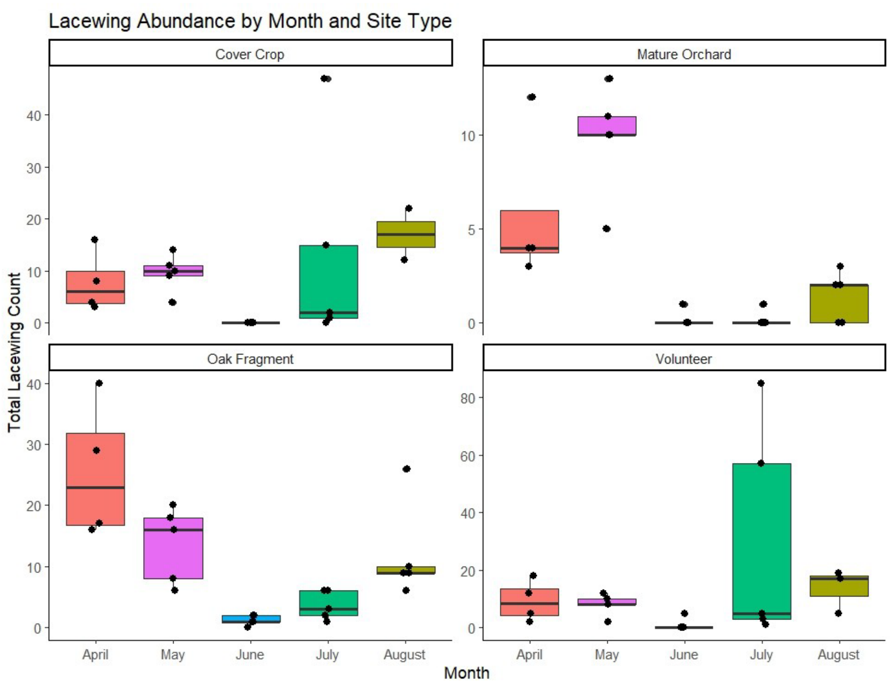


Figure 2: Lacewing abundance by month for each type of habitat sampled in this study.

We also found 12 different subfamilies of beneficial predatory or parasitic wasps, and these were abundant in oak fragments in May and strongly related to the amount of bloom in these fragments (Figure 3) and negatively correlated with the percent of cultivated land surrounding 1km of an oak fragment (Figure 4). This suggests to us that the wasps that are present in May could be particularly reliant on blooming plants as a resource as compared to wasps during other times of the year. In terms of cover crops, this implies that including early blooming species in cover cropping blends may be more effective for enhancing farm habitats for wasps than later season plantings. We are still working on these analyses for on farm habitats.

Finally, we found that leafhoppers, a key vector for cherry-X disease, were highest in mature orchards and in replanted orchards that were not cover-cropped than in other habitats. At least in some months, leafhopper abundance is very low in oak fragments relative to other habitat types, suggesting that while these habitats harbor high numbers of beneficial invertebrates like lacewings, they are not likely to be increasing pest pressure, relative to orchard habitats. Our results suggest that cover cropping with blooming mustards and radish reduces the density of leafhoppers when replanting orchards, compared to not using cover crops.

*Outcomes:* A key outcome of this work was unexpected. We had initially hypothesized that cover crops would be a critical habitat for beneficial insects. While cover crops appeared to play a role in beneficial insect populations and suppressing pest pressure, we found the remnant white oak areas bordering orchards to be the area with the highest beneficial insect density and lowest pest density. This finding suggests an increased emphasis on NRCS practices that improve these oak fragments may be the most beneficial to growers and to beneficial insect communities. To this end, we developed a guidance document for NRCS on practices that could best accomplish this goal.

Hoffman, T.D., Mitchell, S.R., DeBano, S.J. 2023. Wasp Community change across the growing season in Mid-Columbia Basin, Oregon white oak (*Quercus garryana*) habitat fragments. The Ecological Society of America Annual Meeting, August 7, 2023 (conference presentation)

Mitchell, S.R., DeBano, S.J., Adams, C., Melathopoulos, A., Hoffman, T.D. 2023. Cover crops and invertebrates: The good, bad, and everything in between. Hermiston Farm Fair (40 participants). November 29, 2023 (presentation to growers)

Pease, C.G., 2024 Enhancing Pollinator Habitat in Remnant Oak Plant Communities: Wasco and Hood River Counties of Oregon. Xerces Society for Invertebrate Conservation and Oregon State University. 11 pages (publication)

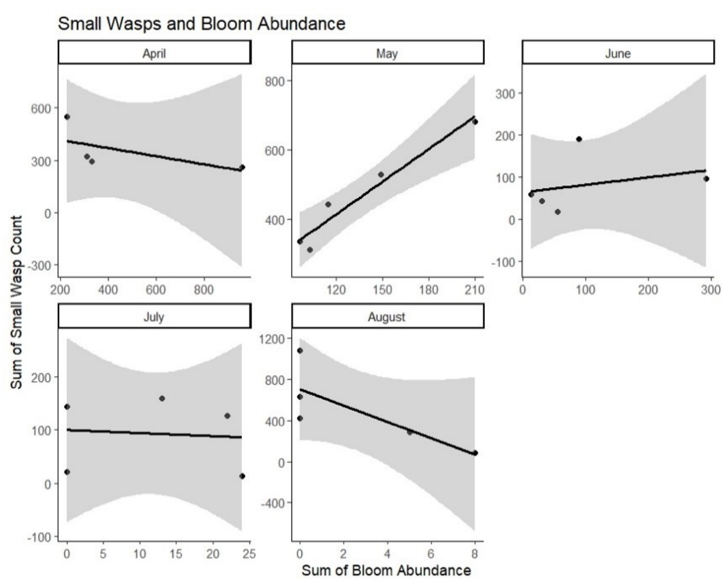


Figure 3: Wasp abundance and bloom abundance in oak fragments for each sample month. Wasp abundance was tightly, positively correlated with bloom abundance in May but not in other

months. Dark lines show linear regression line through those points and gray area shows 95% confidence interval estimate around linear regression line.

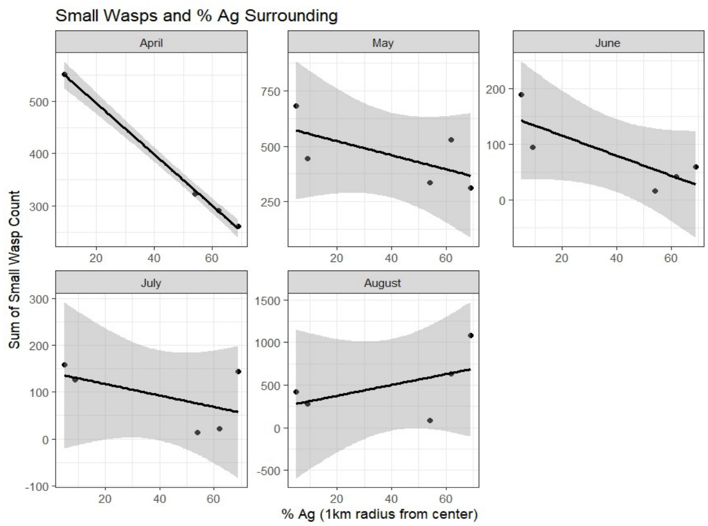


Figure 4: Wasp abundance was significantly negatively correlated with percent cultivated land in the surrounding 1km radius of oak sites in April. Shaded gray region represents 95% confidence interval estimate around regression line.

*Objective 1 – Pesticide exposure to bees section:* We collected 1741 bees over two years (2020, *n* = 771 and 2021, *n* = 808) in sweet cherry production areas (*n* = 115) and the surrounding oak habitat (*n* = 1017), including cover crop habitat (*n* = 390). The main genus of bees identified were: *Andrena* (*n* = 358), *Bombus* (*n* = 78), *Eucera* (*n* = 269), *Halictus* (*n* = 53), *Lasioglossum* (*n* = 91), *Nomada* (*n* = 95), and *Osmia* (*n* = 551). When matched with the identified pollen tested for pesticides from honey bee colonies stationed nearby, 37% (*n* = 637) bees were associated with the pesticide residue tested pollen from plants collected at the same site as the bee. We detected 25 pesticide active ingredients in sweet cherry pollen, 11 ingredients from plants found in the understory of orchards and 28 ingredients found from plants growing in oak habitat. The pesticide hazards (HQ) different bee genera were exposed to varied with bees in the genera *Andrena*, *Bombus* and *Ceratina* having higher HQ values compared to honey bees, while bees in the genera *Eucera* and *Nomada* having lower HQ values. These differences were attributed to contaminated pollen from sources other sweet cherry pollen, which wild species of bees preferred. Plant genera with high HQ values included: *Capsella*, *Lithophragma*, *Stellaria*, and *Taraxacum* which all were associated with average HQ values of ~1000 (Table 1). With the exception of *Stellaria* and *Lithophragma* these were exclusively understory plants within the cherry orchard.

*Outcomes:* Two major outcomes of this work were to identify pesticides that bees are frequently encountering in sweet cherry production, as well as a characterization of how different bee taxa are exposed to pesticides. Our work suggests that the major NRCS practices that reduce drift from cherry trees would have the largest impact in reducing wild bee exposure, as the bee fauna in the region largely avoids *Prunus* species. To this end, we developed a guidance document on reducing drift in sweet cherry systems and on selecting pesticides with lower toxicity to bees.

Carlson, E. A., Entomological Society of America National Meeting, "Pesticide risk in sweet cherry systems of

Oregon: Can the honey bee accurately represent risk to all?" (National Harbor Maryland) (2023) (conference presentation)

Carlson, E., Melathopoulos, A.P, Sagili, R. (in revisions). The power to (detect) change: Can honey bee pollen be used to monitor for pesticide residue in the landscape? PLoS One. (peer reviewed journal article)

Carlson, E., Melathopoulos, A.P, Sagili, R. (submitted). Can the honey bee stand in for all: Estimating pesticide hazard to honey bees and wild bees in sweet cherry orchards and surrounding oak fragment. Scientific Reports (peer reviewed journal article)

Is it feasible to create a state-wide pesticide monitoring network? Oregon State Beekeepers Association Annual Meeting (Bend, OR, October 2023) (84 participants) (presentation to grower)

Cibotti, S. May, E., and Pease, C.G., 2024. Protecting Bees from Pesticides Around Bloom in Oregon Cherries. Xerces Society for Invertebrate Conservation and Oregon State University. 13 pages (publication)

Table 1. Average bee toxic pesticide load (hazard quotient HQ) in pollen to a bee visiting each plant genera during each year and the standard error associated with each plant genera.

| Plant genus | Year | Avg HQ | Standard Error |
|---|---|---|---|
| *Amsinckia* | 2021 | 18.0 | 3.2 |
| *Balsamorhiza* | 2020 | 794.1 | 42.1 |
| | 2021 | 10.9 | 0.52 |
| *Barbarea* | 2021 | 489.0 | 71.5 |
| *Capsella* | 2020 | 980.3 | 120.4 |
| *Claytonia* | 2020 | 558.4 | 61.1 |
| | 2021 | 7.9 | 0.8 |
| *Hydrophyllum* | 2020 | 318.2 | 133.6 |
| | 2021 | 0 | 0 |
| *Lithophragma* | 2020 | 14.8 | *NA* |
| | 2021 | 4810.8 | 1256 |
| *Lupinus* | 2021 | 1.2 | 0.01 |
| *Prunus* | 2020 | 515.3 | 183.3 |
| | 2021 | 65.8 | 1.9 |
| *Stellaria* | 2020 | 1552.7 | 82.2 |
| *Taraxacum* | 2020 | 1352.7 | 115.7 |
| | 2021 | 3501.1 | 609.5 |
| *Vicia* | 2021 | 50.6 | 2.3 |

*Objective 2:*
Flowering plant establishment varied greatly within species and among sites. Among the species tested, sainfoin grew more slowly than desired, borage and buckwheat did not establish in our fields, and common flax yielded poor pollinator habitat. Therefore, these four species were eliminated from the second year of the study.

Site preparation was important for flowering plant establishment. Excellent establishment was observed at McMinnville and Lewis Brown farm where the soil had been tilled prior to planting, while minimal germination at the untilled Corvallis trial location was observed. Likewise, planting pollinator species in a weed-free area improved the crop establishment. Strong germination of grass weeds at the McMinnville and Corvallis sites resulted in low crop establishment in the untreated plots, while nonselective glyphosate, applied at planting, performed as well or better than all other treatments for phacelia, poppy, and farewell to spring. This result emphasizes the importance of beginning with a weed-free area. Similarly, the preemergent herbicides with no activity on grasses performed worse in these areas (Figure 5).

Weed control from the preemergent herbicides typically lasted 5 to 8 months. At the tilled McMinnville, OR location, glyphosate, indaziflam, napropamide, flumioxazin, and simazine effectively controlled weeds through 8 months after treatment. At the untilled Corvallis, OR location only glyphosate, indaziflam, and napropamide provided weed control through 8 months after treatment. By December 2021, 14 months after treatment, only indaziflam continued to provide control at either location. Of the post-emergent herbicides only rimsulfuron (Matrix) controlled weeds and coverage due to high pressure from grass weeds, but this control was not long-lasting.

Weed pressure was very low at the Lewis Brown farm trial, but this was the only location with both monocot and dicot weeds. At Lewis-Brown, post-emergent treatments rimsulfuron and mesotrione best controlled monocot or dicot weeds, respectively. Preemergent treatments indaziflam, napropamide, flumioxazin, pendimethalin, and simazine effected monocot weed coverage and isoxaben, flumioxazin, and pendimethalin plots had lower dicot weed coverage at Lewis-Brown.

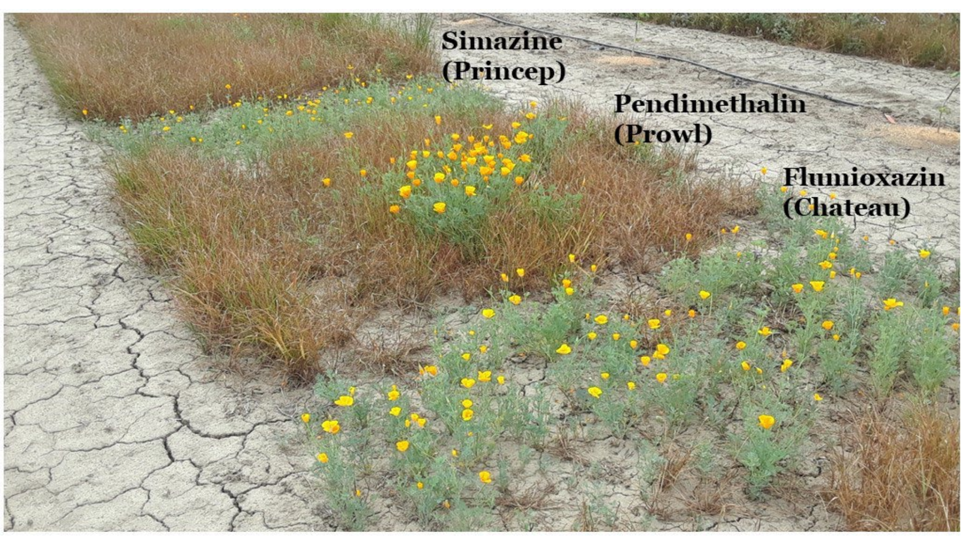

Figure 5: California poppy tolerated pendimethalin and flumioxazin when treated just after seeding. Also seen here, tolerance to simazine was noted when California poppy was treated 6 months after seeding.

Many species tolerated one or several preemergent herbicides well when planted just before application, and a few post-emergent herbicides showed promise as being safe for several species. When a species tolerated a preemergent treatment, flowering was improved relative to the control. The data from the second year also revealed a long-term benefit to our weed control treatments, with every species displaying an increase in coverage from at least one preemergent herbicide treatment (Table 2). Several post-emergent treatments improved crop establishment for year two (Table 2) but never outperformed the preemergent treatments.

Table 2: Seven preemergent herbicides were tested on seven species seeded one day prior to herbicide application and reseeded one year after. Species tolerance to the treatments was noted in three trials.

| Treatment | Species (Herbicide Tolerance) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Preemergent** | Hairy vetch | | Phacelia | | California poppy | | Globe gilia | | Farewell to spring | | Sweet Alyssum | | Sainfoin | |
| | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 | Y1 | Y2 |
| Indaziflam (Alion) | | | | | | | | | | | | | - | * |
| Isoxaben (Trellis) | T | | | | | | | | T | | | | | |
| Napropamide (Devrinol) | | | T | * | | | T | | | | T* | | T | |
| Flumioxazin (Chateau) | | | | | T | * | | | | * | | | | * |
| Pendimethalin (Prowl) | | * | | | T | * | | | | | | * | | |
| Princep (Simazine) | T | | | | | | | | | * | | * | T | |
| Mesotrione (Motiff) | | * | | | | | | * | | | | * | | |
| Number of studies with good plant establishment | 2/3 | | 3/3 | | 3/3 | | 1/3 | | 2/3 | | 1/3 | | 1/2 | |

T indicates which species tolerated a particular herbicide. NT – not tolerant, '-' no information.
* indicates the herbicide had a beneficial effect on the pollinator coverage when sown one year after preemergent herbicides were applied.

Though there were clear species/herbicide combinations that encouraged successful crop establishment, an individual species often a treatment at one location but not at another. The tolerances were confirmed by successive trials, but the trial at Lewis-Brown showed that an excess of species tolerated various herbicide applications (Figure 6). This location received greater care in preparation prior to seeding and was seeded at higher rates, which may have improved tolerance.

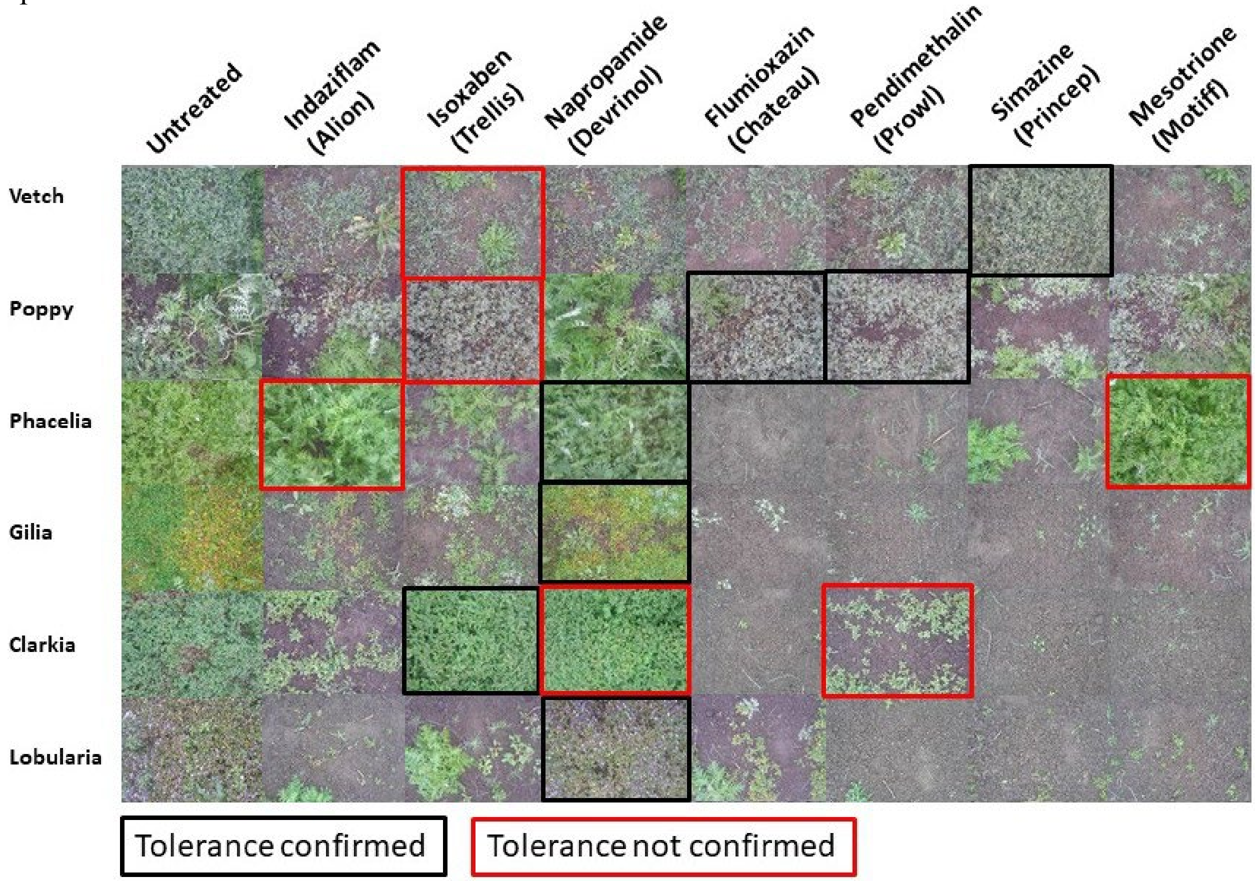


Figure 6: Crop coverage two months after seeding and the application of seven preemergent herbicide applications showed many species to be tolerant. Red boxes indicate species/herbicide combinations that were injured. Black boxes show tolerant combinations that were seen and confirmed.

Sainfoin was a species not planted at Lewis-Brown due to its slow growth rate, but it did have some tolerance to indaziflam (Alion). The first small plants were observed 8 months after treatment, but by the following year they had grown to twice the size of the plants in other plots. Though there were fewer plants in the indaziflam-treated plots, the lack of weed competition likely allowed them to grow to a greater size. This result was only seen at one of the two locations where sainfoin was seeded.

*Outcomes:*

We noted a great deal of variation among the three locations, but several conclusions can be drawn. Flowering plant tolerance was highly species-specific and varied by location, with better site preparation and more species-herbicide combinations resulting in successful crop establishment. Pre-emergent treatments were most effective in improving flowering plant

establishment while also providing greater long-term weed control. Herbicide treatments also improved crop establishment when species were seeded a year after treatment.
Planting recommendations can be made based on the tolerances identified multiple times in our trials (Table 3). The inconsistency observed in our results suggest that more testing could ensure species will establish when using herbicides, especially indaziflam. These results will help facilitate the adoption of blooming cover crops in hazelnut production.

Hill, R.J, Melathopoulos, A., Moretti, M.L. Pollinator species establishment and the impacts of herbicides. HortScience (in preparation) (peer reviewed journal article)

Hill, R.J., King, D.R., and Moretti. M.L. Overcoming Weed Competition During Pollinator Habitat Establishment. Proceedings of the Western Society of Weed Science. (Denver, CO) (March 6, 2024) (conference presentation)

Pollinator Cover Crops in Orchards. Lewis Brown Horticulture Farm, Oregon State University, Corvallis, OR, April 29, 2022 (18 contacts, mostly Soil and Water Conservation staff) (presentation to growers)

Melathopoulos, A. Weed management to help bees. Chemical Applicator Short Course Day, Pesticide Safety and Education Program Oregon State University (online) January 3, 2024 (253 participants) (presentation to growers)

Melathopoulos, A. Weed management to help bees. Willamette Valley Expo, Albany, OR, November 16, 2023 (164 participants) (presentation to growers)

Melathopoulos, A. Weed management to help bees. Washington Weed Conference, Wenatchee, WA, November 3, 2023 (326 participants) (presentation to growers)

Pease, C.G., 2024. Pollinator Cover Crops in Hazelnut Orchards. Xerces Society for Invertebrate Conservation and Oregon State University. 4 pages (publication)

Table 3: Cover crop compatibility depending on pre-emergent herbicide application timing.

| | **Concurrent with application** | **6 months after application** |
|---|---|---|
| **Indaziflam (Alion)** | None | Sainfoin |
| **Isoxaben (Trellis)** | Farewell to spring | Hairy vetch, farewell to spring |
| **Napropamide (Devrinol)** | Phacelia, globe gilia, sweet alyssum, sainfoin | Phacelia, globe gilia, farewell to spring, sweet alyssum, sainfoin |
| **Flumioxazin (Chateau)** | California poppy | California poppy, farewell to spring, sainfoin |
| **Pendimethalin (Prowl)** | California poppy | California poppy |
| **Rimsulfuron (Simazine)** | Hairy vetch, sainfoin | Hairy vetch, sainfoin, phacelia, California poppy, globe gilia, farewell to spring, sweet alyssum |
| **Mesotrione (Motiff)** | None | None |

*Objective 3:*
In the 2020/2021 growing season, the total annual dry matter yield (DMY) of diverse pastures was greater ($p < 0.01$) than the DMY of simple grass-dominated, and legume pastures. In the 2021/2022 growing season, the total annual DMY of simple and diverse pastures were similar. However, the legume pastures produced 27–30% less than simple and diverse pastures.

In both years, the lamb growth rates from legume pastures were greater ($p < 0.01$) than the other pasture types. However, the live weight gain from all three pasture types were comparable ($p$ = 0.23). Lambs grew faster in the first half of spring in both years. Their growth rates reduced as the season progressed. The diverse pastures provided greater ($p < 0.01$) lamb total liveweight production than simple pastures and legume pastures by 38 and 220 kg ha$^{-1}$, respectively, in spring 2021. While the total lamb liveweight gains were 745, 628 and 581 kg ha-1 for diverse, simple and legume pastures, respectively, in 2022, the difference was not significant ($p$= 0.20).

Averaged across the entire grazing period, bloom density of pastures was 1.9, 8.7 and 50.4 flowers per m$^2$ for simple, diverse, and legume pastures, respectively, in 2021 (Figure 7 a,b). A pasture treatment × period interaction ($p$< 0.01) was detected as the bloom density for simple pastures was low and relatively stagnant as compared to diverse and legume pastures. In both 2021 and 2022, simple and diverse pastures had a similar trend for bloom density. In 2021, legume pastures had a high bloom density at the beginning of the season and began to gradually decline starting in late May until terminating in July.

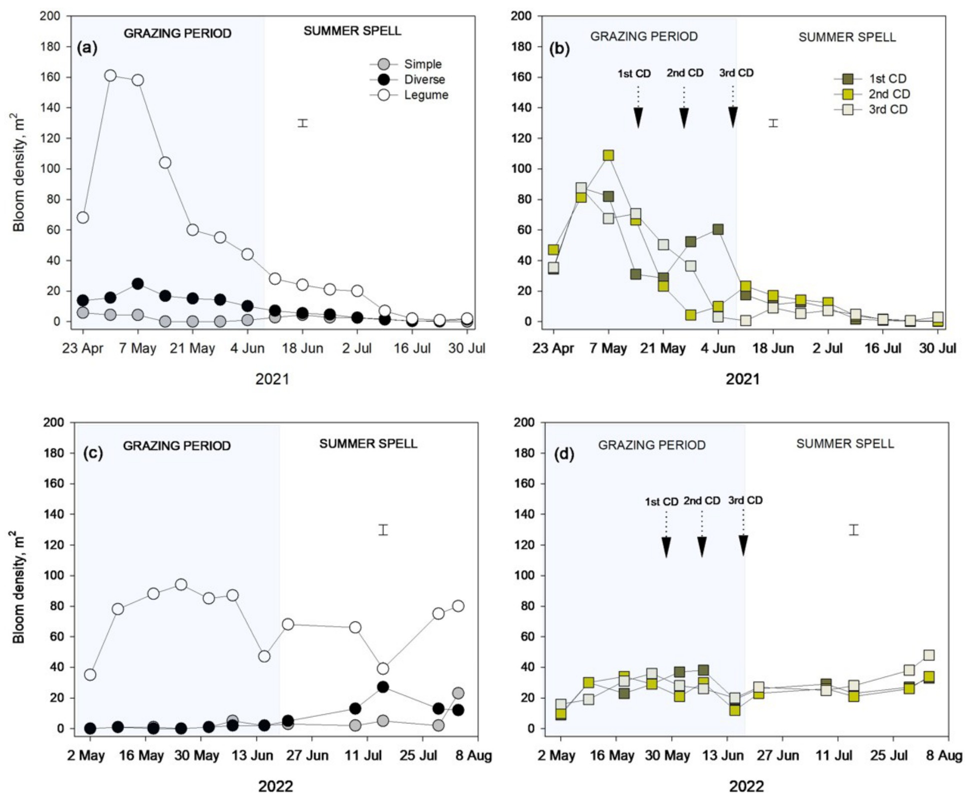


Figure 7. Bloom density as affected by pasture type (**a**,**c**) and closing date (**b**,**d**) (CD). Bars represent SEM for pasture × closing date × period interaction.

In 2022, the bloom density in legume pastures remained somewhat constant throughout, aside from mid-June and mid-July, where bloom density decreased (Figure 7 c,d). There was a three-way interaction ($p < 0.01$) among pasture treatment, closing date, and period for bloom density for the grazing period following the first closing date. Neither the closing date, nor the period had any effect on simple grass pastures for bloom density. Earlier closing of legume pastures led to greater bloom density as compared to mid and late closing dates, but the difference in bloom density induced by closing dates disappeared after the first week of July.

Bee visitation across 2021 was similar between simple and diverse pastures, with the highest ($p < 0.01$) visitations being displayed in the legume pastures (Figure 8 a,b). A three-way interaction ($p < 0.01$) was detected among pasture treatment, closing date, and period for bee visitations. Bee visitations in legume pastures had a peak in early May and began to decrease sharply starting in mid-May until they were comparable to simple and diverse pastures in early July. The closing date treatments did not have any effect on the bee visitations for simple and diverse pastures, but bee visitations were higher with earlier closing (first) then mid (second) and late (third) closing for legume pastures. In 2022, bee visitations were similar ($p > 0.05$) across treatments, with legume pastures showing a slightly higher number of visitations (Figure 8 c). In 2022, no discernable differences among closing dates were observed for the bee visitations (Figure 8 d).

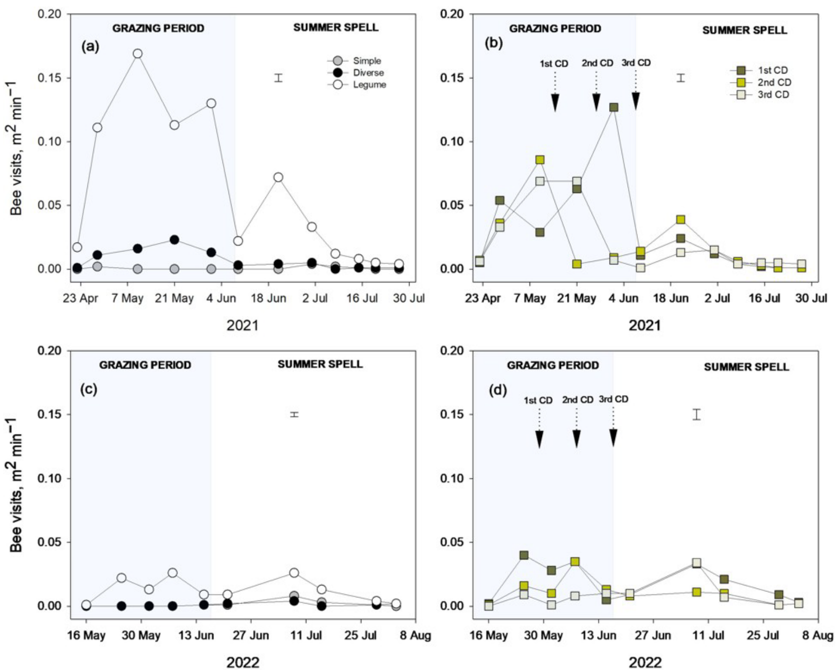


Figure 8. Honey bee visits as affected by pasture type (**a**,**c**) and closing date (**b**,**d**) (CD; (**b**,**d**)). Bars represent SEM for pasture × closing date × period interaction.

*Outcomes:*

The findings of this study determined that legume pastures provided the greatest benefit for grazing animals and floral bloom available for bees, while diverse pastures displayed a greater benefit for overall herd weight production. Potentially, legume pastures can only be used for grazing for one to two years before overseeding them with grasses or establishing them at a higher seeding rate and broadcasting seeds between years. Diversification of the pastures allowed for the utilization of different growing strategies, providing bloom through mid-summer for pollinators, where balansa clover was the most prevalent of legume species in the current study across both years. Lastly, the closing date had minimal effects on bloom density and bee visitations in this study. This implies further research is needed in that area, using the perennial forb species with late blooming characteristics. To this end, this research led to a large-scale evaluation of forage plants for pollinators, which is summarized in an NRCS guidance document produced through this grant.

Caudillo, M., Melathopoulos, A., Smallman, M., Kinkaid, S. A., Prado-Tarango, D. E., & Ates, S. (2023) Designing Dual-Purpose Management Strategies for Sheep Production and Pollinators in Dryland Pastures. Proceedings of XXV International Grassland Congress, Kentucky, USA (14-19 May 2023) (published proceedings and conference presentation)

Caudillo, M., Melathopoulos, A., Prado-Tarango, D. E., Smallman, M., Taylor, S. A., & Ates, S. 2023. Designing management strategies for sheep production and bees in dryland pastures. Agronomy, 14(1), 24. doi.org/10.3390/agronomy14010024 (peer reviewed journal article)

Willamette Valley Pasture Management for Pollinators and Livestock. Oregon State University Livestock Research Center, OSU, Corvallis, OR June 22, 2022 (35 contacts) (field day)

Pease, C.G., 2024. Pollinator Plants for Pastures. Xerces Society for Invertebrate Conservation and Oregon State University. 2 pages (publication)

# Appendix: Guideline Documents Produced from the Project

Cibotti, S. May, E., and Pease, C.G., 2024. Protecting Bees from Pesticides Around Bloom in Oregon Cherries. Xerces Society for Invertebrate Conservation and Oregon State University. 13 pages (publication)

Pease, C.G., 2024 Enhancing Pollinator Habitat in Remnant Oak Plant Communities: Wasco and Hood River Counties of Oregon. Xerces Society for Invertebrate Conservation and Oregon State University. 11 pages (publication)

Pease, C.G., 2024. Pollinator Cover Crops in Hazelnut Orchards. Xerces Society for Invertebrate Conservation and Oregon State University. 4 pages (publication)

Pease, C.G., 2024. Pollinator Plants for Pastures. Xerces Society for Invertebrate Conservation and Oregon State University. 2 pages (publication)

# Enhancing Pollinator Habitat in Remnant Oak Plant Communities

*Oak savanna at Memaloose Overlook (photo: Matthew Shepherd).*

The preservation and restoration of oak plant communities in Wasco and eastern Hood River counties can be important for many reasons. These habitats are dominated by the Oregon white oak (*Quercus garryana*) and ponderosa pine (*Pinus ponderosa*). Because of the historical clearing of vast areas for grazing and agriculture, only a small percentage of these oak savannas and woodlands in Oregon remain. Research conducted by Oregon State University (OSU) as a part of an USDA Natural Resources Conservation Service (NRCS) Conservation Innovation Grant (CIG) and data collected by participants in the Oregon Bee Project has found that native plant habitat in remnant oak stands in Wasco County provide the most important habitat for sustaining the bee diversity in the region. These oak plant communities also serve as important habitat for other beneficial (predator and parasitoid) insects that attack crop pests.

In addition to pollinators and other beneficial insects, these plant communities also play a critical role in supporting wildlife diversity, surpassing that of some conifer forests. They provide essential refuge for the imperiled western gray squirrel and many bird species, such as dark-eyed juncos, goldfinches, nuthatches, wild turkeys, and acorn and pileated woodpeckers. Beyond their ecological significance, these habitats offer many benefits for farms and ranches, such as providing shade for livestock or acting as natural buffers that protect streams from sediment or manure runoff.

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Table 1 (page 7) includes the plant species that occur in association with white oak that are most attractive to native bees in oak habitats. These plants also attract a wide variety of beneficial insects including parasitoid wasps in the family Ichneumonidae, predaceous wasps in the family Vespidae (paper wasps and yellowjackets), and predaceous lacewing (*Chrysopa* spp. and *Chrysoperla* spp.). Oak habitats were found to be especially important for lacewings in April and May and then again in August. Similarly, April, May, and August were the primary months when wasps and native bees utilized oak habitats.

## Purpose

The purpose of this document is to provide information on the best techniques to assess, manage, enhance, or establish habitat for pollinators and beneficial insects in remnant oak plant communities in Wasco and Hood River counties. This document can be used by landowners, NRCS conservation planners, and other conservation professionals to implement conservation practices. Depending upon existing weed pressure and the composition of native plants in remnant oak habitat near farms, these plant communities can be managed to remove non-native weeds competing with important pollinator plants or diversified with native plant species that provide important habitat for native pollinators.

Increasing the diversity of native flowering plants near orchards and other agricultural areas provides nectar and pollen resources for pollinators and beneficial insects, and also serves as a refuge from pesticide applications. Additionally, the presence of native bees and various predaceous and parasitic insects within white oak plant communities can provide benefits to farmers, contributing to enhanced pollination and pest control in adjacent orchards. The management or enhancement of white oak habitat can be important for ecological conservation and provide ecosystem services for agriculture in Hood River and Wasco counties.

## Site Characteristics

Prior to planning pollinator habitat conservation practices, evaluation of site characteristics and existing plant community is the first critical step in the habitat planning process. Assessing and documenting factors such as soil composition, topography, water drainage patterns, and microclimates can help determine potential plant community composition. At the same time, planners or interested landowners should assess which, if any, native plant species that are valuable to pollinators are present (see Table 1 on page 7). Inventories of introduced and invasive species will help determine if the best course of action is to manage the site to reduce weed pressure to release the native plant community, to interplant additional native plants, or to conduct significant weed eradication and site preparation to replant or restore diverse native pollinator habitat.

Understanding the following site characteristics will help determine the course of action for pollinator habitat conservation in Wasco County oak habitat:

ö Native plant species: Evaluate what species are present. Refer to Table 1 and the plant identificiation resources listed on page 11 to assist in identifying important forbs for native bees and other beneficial insects.

ö Weed/invasive species pressure: Take note of the weed species present. Dominant weeds in this region include cheatgrass, bulbous bluegrass, medusahead, and diffuse knapweed. Other grasses that require additional considerations for site preparation include introduced bunchgrasses such as crested wheatgrass, tall wheatgrass, and sheep fescue, and rhizomatous grasses such as intermediate wheatgrass, and smooth brome.

ö Soil: Soil type may affect both the types of plants that could occur on site, as well as the type of tools that may be used to install habitat. Soils of remnant oak plant communities in Wasco County are often deep well-drained loam, silt loam, or cobbly/gravelly loam. However, many sites with remnant oaks close to orchards may have thin, rocky soil that affects the ability to cultivate the site or to utilize no-till or range drills. It is also important to consider that some plant species are more well-suited to rocky or gravelly soil. Species that can tolerate these conditions and typically occur in rocky soils include bigseed lomatium, arrowleaf buckwheat, andtall buckwheat.

- ö Risk of Pesticide Drift into Plantings: Habitat must be protected from pesticides. Only sites with low risk for pesticide drift should be established as new habitat. The need for protection is greatest from insecticides and bee-toxic fungicides, but also broad-leaf herbicides that could damage native wildflowers and shrubs. This includes some pesticides approved for use on organic farms. Pesticide use in orchards is of particular concern in this region. Application of insecticides and fungicides with air blast sprayers has a high potential for drift. Buffers of 60 ft from pesticide application by air blast sprayer to pollinator habitat is recommended.

- ö Risk of Introducing Unwanted Plants and Disturbing Current Native Species: Take precautions by cleaning equipment and boots prior to working in the area to prevent the movement of invasive species into the site. Ideally, survey the site for native species in the spring, summer, and fall prior to planning the habitat to avoid disturbing any remnant plant species. Disturbing an oak site may have unwanted consequences of introducing invasive plant species and affecting native species present on site.

- ö Risks to Non-Target Wildlife Species: The planner should be mindful of potential impacts on other wildlife. An example is the disturbance or destruction of a habitat element such as large downed logs in various states of decay which can provide protection to terrestrial amphibians, reptiles, birds, and small mammals. In addition, downed wood provides these animals with food such as insects, fungi, and seeds.

- ö Irrigation Availability: Many areas may not have irrigation available. If this is the case, seeding habitats may be best. Establishing plants from plugs, pots, or bare roots may require irrigation.

- ö Site Accessibility: New habitat should be accessible to equipment for planting and maintenance operations if needed. Areas with a slope greater than 30% may not be accessible by tractors. Areas that are not accessible to seeding equipment can be planted with plugs or be seeded with broadcast seeder (e.g., ground driven cone spreader, belly grinders) or hand broadcast.

- ö Sunlight: Many of the plants included in this specification thrive in full sun, but some species tolerate partial or full shade. Refer to Table 1 for more details on sunlight requirements for different plant species.

## Pollinator Habitat Enhancement Decision-Making

The characteristics listed above will help guide conservation planning to enhance habitat for pollinators and beneficial insects. Depending on the starting condition of the site, determine which strategy for enhancing pollinator habitat is the best. Refer to the flow chart in Figure 1 (page 4) to help determine which course of action to take. Establishing new habitat is not always the most effective course of action. NRCS conservation practices such as Weed Treatment (315), Brush Management (314), or Wildlife Habitat Planting (420) can be used to implement the strategies below. Three general approaches to enhancing habitat are outlined here:

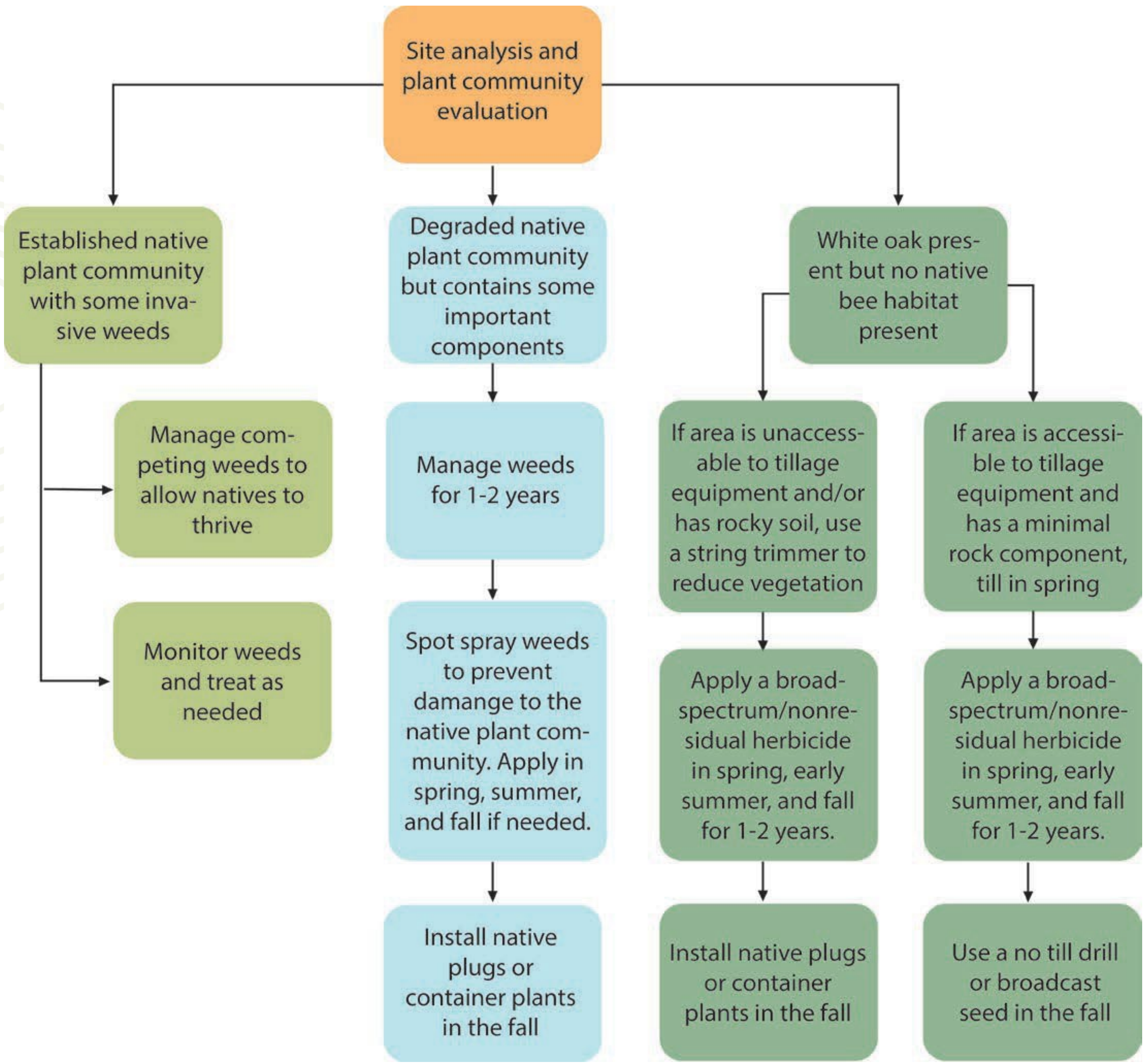
1. Manage weeds to release natives. If the site has a remnant community of native plants that provide good pollinator habitat it may be best to suppress weeds by implementing NRCS practices such as Weed Treatment (315) or Brush Management (314) to allow the native plant community to thrive. Careful spot spraying of herbicides with hooded sprayer wands or wick applicators can minimize impacts on adjacent plants. It is common for some sites to be dominated by invasive grasses with a remnant population of native forbs. Consider the use of grass-selective herbicides in this scenario to help release the native forbs from grass competition. Alternative methods to manage weeds include mechanical control such as the use of string trimmers, mowers, or hoes for scalping. After implementing these practices evaluate whether this approach is sufficient or whether interplanting with natives (approach #2 below) is needed to fill the spaces and prevent weed encroachment.

2. Manage weeds and interplant native pollinator plants. If the site has a degraded native plant community that is lacking in some key pollinator plants this may be the best approach. Implement NRCS practices Weed Treatment (315) or Brush Management (314) followed by Wildlife Habitat Planting (420). If the weed pressure is low, several spot

applications of herbicides in areas without natives will remove non-natives. If using a broad leaf non-residual herbicide, plant forb or grass transplants 72 hours after the last herbicide application in the fall to occupy the space as soon as possible. Select and plant forb or shrub species that are not represented in the site to provide a broad range of pollen and nectar resources in spring, summer, and fall. Small transplants or plugs may need supplemental water the first year during dry periods.

3. Restore native pollinator habitat. If very few or no native plants are present it may be best to remove the current vegetation and seed or transplant native pollinator plants and native grasses. Implement NRCS practices Herbaceous Weed Treatment (315) or Brush Management (314) if needed. Depending on the weed pressure of the site, preparation may take 1–2 years to reduce the weed seed bank. After proper site preparation implement the Wildlife Habitat Planting (420) practice.

**Figure 1. Decision tree for enhancing pollinator habitat in white oak plant communities.**



## Site Preparation

Site preparation for NRCS conservation practice Wildlife Habitat Planting (420) for pollinators and beneficial insects may take up to two years depending on the weeds present on the site. Sites with perennial weeds typically take two years of weed management before planting. Familiarity with the life cycle of on-site weeds will facilitate appropriate timing of management activities (e.g., see above for common examples in this area). There are 3 steps to site preparation.

1. Remove existing vegetation. Before controlling invasive weeds, remove any accumulated grass and weed thatch. Thick grass thatch will prevent future seed planting from having adequate seed-to-soil contact and thatch will prevent container plantings from establishing well.

    ö Controlled burns can be an effective method to reduce grass thatch, however without experienced controlled burn technicians this is not recommended.

    ö If the site is accessible and on level ground, the area can be mowed and hayed to remove accumulated thatch.

    ö If the site is accessible by tractor, tillage can be an effective way to remove the current vegetation. Mowing followed by a harrow can be used to reduce a moderate amount of vegetation. Thickly built-up thatch may necessitate heavy disks or even a moldboard plow to bury the plant residue.

    ö Covering small areas with silage tarps, weed mats, or other heavy tarps for 6–9 months can be an effective method to reduce existing vegetation and reduce surface weed seed. Lay out silage tarps (or other black tarps) and hold down the edges with sandbags, cinder blocks, rocks, or other heavy items. Several months in place (in spring) will help remove the vegetation from the area. Keep in place for at least 6–9 months to use this method for weed seed bank reduction.

    ö Particularly problematic perennial weeds should be treated early on in the process with targeted herbicide applications to remove them from the planting area. Some herbicides that are effective on composite family (Asteraceae) weeds may have residual activity for 1–3 years.

2. Create a seeding surface (if seeding habitat)

    ö No-till drills can seed into the ground with minimal or no tillage and generally will require a surface with minimal thatch that has been mowed as low as possible to break down the plant residue that remains. Excessive thatch can prevent a no-till drill from placing the seed on the soil and potentially clog the colters.

    ö Broadcast seeding methods such as hand seeding, cone broadcast spreading, and drop seeding will necessitate a fine firm seedbed free of plant residue. A pass with a harrow or very shallow disk followed by a culti-packer would produce a fine seedbed for broadcast planting.

3. Reduce the weed seed bank. After creating a seed bed in the spring of the planting year, reduce the weed seed bank in one of the following ways. It is important to minimize tillage after this stage as it will bring dormant weed seed to the surface setting back any reduction in the surface seed bank.

    ö *Chemical fallow*. Apply a broad-spectrum, non-residual herbicide to prevent weed growth in the spring, early summer, and fall. The fall application can occur as late as 72 hours prior to planting. Apply herbicide as often as needed to prevent weed growth and accumulation of plant residue. If needed, repeat this process for a second year if the site has high weed pressure.

- *Flaming*. For small sites with low risk of fire spread, flaming is a technique using a propane flamer to kill small germinating weeds before they grow tall. Flame the seed bed repeatedly spring through fall as seeds germinate (as often as every 4 weeks). Repeat this process for a subsequent year if weed pressure remains high.

- *Solarization*. Solarization should only be used in full sun areas that have a low risk of erosion and are accessible to mowing, water, and tillage equipment. Begin the solarization process in late May and leave it in place through the summer. Mow and till the soil to create a seed bed. Water the site and place UV-resistant clear plastic (such as greenhouse plastic) over a moist seed bed. Solarization is only effective when starting with a moist soil bed. If irrigation is not available, solarization plastic must be placed down on the area immediately after a rain event in late spring. Bury the edges of the plastic to make sure the heat is sealed in. Leave the plastic in place until the fall. Repair all holes in the plastic as soon as possible with greenhouse plastic repair tape. Remove the plastic and plant immediately. Do not till.

- *Smothering (silage tarping)*. Smothering with light-blocking plastic can be used to reduce the weed seed bank and help decompose surface vegetation. This process may stimulate the germination of some seeds and subsequent death and decomposition of surface plant residue including seeds. Periodically removing the tarp to stimulate seed germination and promptly recovering the area can increase the effectiveness of this method. It is generally less effective on perennial weeds.

### Typical Problem Weeds in Oak Plant Communities

Here are some common invasive weeds that require additional consideration in remnant oak habitat. Mowing alone will not control these species. Refer to the PNW Weed Management Handbook for all herbicide recommendations. If these species or other weeds are too dominant on a site, significant effort to remove these plants from the site will be required before a more intensive restoration.

- Cheatgrass can typically be controlled with repeated applications of broad-spectrum nonresidual herbicides like glyphosate or grass-specific herbicides. This species typically becomes less important over time as the planted habitat takes over the planting area.

- Diffuse knapweed and Canada thistle are difficult to remove from a site without significant forethought and treatment. Avoid sites with knapweed or Canada thistle if at all possible. Effective herbicides for control of knapweeds and Canada thistle can have residual effects on broad-leaved plants in the area for 1–3 years depending on the active ingredient used.

- Medusahead can be suppressed with mowing during late spring during the early flowering stage, but this tactic will not reduce populations enough for native species restoration. Prescribed burning in late spring, when the seeds are still on the plant, can kill the seeds and eliminate thatch for subsequent planting. Nonselective and residual herbicide applications, such as glyphosate at tillering in spring or just before seeds are produced, can be effective as well.

- Bulbous bluegrass is best controlled with herbicide. However it can also be effectively controlled with early season cultivation or tillage.

- Himalayan blackberries can be suppressed by repeated mowing, but this technique will not eliminate them for the purposes of restoration. Plants with established crowns will re-sprout for many years before their root resources are exhausted. Hand digging or mechanical removal of plant crowns with hand tools such as shovels and picks or with chains can be effective if repeated to remove re-sprouting roots. Herbicide treatment is the most effective method to remove blackberries and prevent regrowth.

## Plant Selection

Select plant species that provide pollen and nectar resources in the early, mid, and late seasons. Native grasses can also provide habitat for overwintering and nesting bees and other beneficial insects. Grasses are typically included at a rate of 20–25% of the number of seeds planted per square foot.

### Table 1. Commercially available pollinator plants that occur in Columbia Gorge white oak plant communities.

| Common Name | Species | Bloom Period Early | Bloom Period Mid | Bloom Period Late | Density* | Availability | Sunlight Requirements |
|---|---|---|---|---|---|---|---|
| **Forbs** | | | | | | | |
| **Common Yarrow** | *Achillea millefolium* | | X | | 2 ft spacing or 0.5 PLS lb./ acre | Seed or Container | Full sun, Part Shade |
| **Menzies' fiddleneck** | *Amsinckia menziesii* | X | | | 9 PLS lb./acre | Seed | Full Sun, Part Shade |
| **Woollypod milkvetch** | *Astragalus purshii* | X | | | 9 PLS lb./acre | Seed | Full Sun |
| **Carey's balsamroot** | *Balsamorhiza careyana* | X | | | 2 ft spacing or 7–15 PLS lb./acre | Seed or Container | Full Sun, Part Shade |
| **Arrowleaf balsamroot** | *Balsamorhiza sagittata* | X | | | 2 ft spacing or 7–15 PLS lb./acre | Seed or Container | Full Sun, Part Shade |
| **Arrowleaf buckwheat** | *Eriogonum compositum* | X | | | 1–2 ft spacing | Container | Full Sun |
| **Tall buckwheat** | *Eriogonum elatum* | X | X | | 2–3 ft spacing or 3 PLS lb./ acre | Seed or Container | Full Sun |
| **Snow buckwheat** | *Eriogonum niveum* | | X | X | 2 ft spacing or 3 PLS lb./ acre | Seed or Container | Full Sun, Part Shade |
| **Oregon sunshine** | *Eriophyllum lanatum* | | X | | 1 ft spacing or 4 PLS lb./ acre | Seed or Container | Full Sun |
| **Whitestem frasera** | *Frasera albicaulis* | X | | | 2 ft spacing | Container | Full Sun |
| **Blanket flower** | *Gaillardia aristata* | | X | X | 2 ft spacing or 6 PLS lb./ acre | Seed or Container | Full Sun |
| **Ballhead waterleaf** | *Hydrophyllum capitatum* | X | | | 2 ft spacing | Container | Full Sun, Part shade, Full Shade |
| **Columbia desert parsley** | *Lomatium columbianum* | X | | | 20 PLS lb./ acre | Seed | Full Sun, Part Shade |

| Common Name | Species | Bloom Period Early | Mid | Late | Density* | Availability | Sunlight Requirements |
|---|---|---|---|---|---|---|---|

FORBS

| Common Name | Species | Early | Mid | Late | Density* | Availability | Sunlight Requirements |
|---|---|---|---|---|---|---|---|
| **Fernleaf biscuitroot** | *Lomatium dissectum* | X | | | 3 ft spacing or 20 PLS lb./ acre | Seed or Container | Full Sun, Part Shade |
| **Klickitat biscuitroot** | *Lomatium klickitatense* | X | | | 2 ft spacing | Container | Full Sun, Part Shade |
| **Bigseed lomatium** | *Lomatium macrocarpum* | X | | | 5–10 PLS lb./ acre | Seed | Full Sun, Part Shade |
| **Barestem biscuitroot** | *Lomatium nudicaule* | X | | | 2 ft spacing or 20 PLS lb./ acre | Seed or Container | Full Sun, Part Shade |
| **Butterfly-bearing biscuitroot** | *Lomatium papilioniferum* | X | | | 23 PLS lb./ acre | Seed | Full Sun, Part Shade |
| **Nineleaf lomatium** | *Lomatium triternatum* | X | | | 20 PLS lb./ acre | Seed | Full Sun, Part Shade |
| **Silverleaf phacelia** | *Phacelia hastata* | X | | | 7 PLS lb./acre | Seed | Full Sun, Part Shade |

SHRUBS

| Common Name | Species | Early | Mid | Late | Density* | Availability | Sunlight Requirements |
|---|---|---|---|---|---|---|---|
| **Tall Oregon grape** | *Berberis aquifolium* | X | | | 5 ft spacing | Container | Full Sun, Part Shade |
| **Deerbrush** | *Ceanothus integerrimus* | | X | | 8 ft spacing | Container | Full Sun |
| **Rubber rabbitbrush** | *Ericameria nauseosa* | | X | X | 3 ft spacing or 0.5 PLS lb./acre | Seed or Container | Full Sun |

GRASSES

| Common Name | Species | Early | Mid | Late | Density* | Availability | Sunlight Requirements |
|---|---|---|---|---|---|---|---|
| **Bluebunch wheatgrass** | *Pseudoroegneria spicata* | - | - | - | 1 ft spacing or 8 PLS lb./acre | Seed | Full Sun, Part Shade |
| **Secund bluegrass** | *Poa secunda* | - | - | - | 1 ft spacing or 6 PLS lb./acre | Seed | Full Sun, Part Shade |
| **Idaho fescue** | *Festuca idahoensis* | - | - | - | 1 ft spacing or 8 PLS lb./acre | Seed | Full Sun, Part Shade |
| **Junegrass** | *Koeleria macrantha* | - | - | - | 1 ft spacing or 2 PLS lb./acre | Seed | Full Sun, Part Shade, Full Shade |

**BASED ON RESEARCH FROM OREGON STATE UNIVERSITY, AND DATA COLLECTED BY VOLUNTEERS OF THE OREGON BEE PROJECT, THESE PLANTS HAVE BEEN DEMONSTRATED TO BE THE MOST IMPORTANT SPECIES FOR NATIVE POLLINATORS IN WASCO COUNTY OAK HABITATS.**

*** PLUG DENSITY (SPACING) OR SEEDING RATE (PLS LB./ACRE). DATA IN THIS TABLE IS FOR BROADCAST SEEDING RATES FOR A SINGLE SPECIES. DRILL SEEDING RATES ARE TYPICALLY HALF OF BROADCAST RATES. THESE PLANTS ARE TYPICALLY PLANTED IN A MIX, THEREFORE WHEN DESIGNING A SEED MIX, RATES ARE REDUCED ACCORDING TO THEIR PERCENTAGE IN THE MIX.**

**Planting**

Determining the best method for planting is dependent on the site conditions, available equipment, and site accessibility. Site conditions such as weed pressure, water availability, and slope may play a role in what planting methods are appropriate.

### *Transplanting*

Plug or container planting is one method for establishing plants, especially for woody perennials and shrubs. Plugs can also be used to establish herbaceous forbs but entail higher labor input and plant material costs than seeding. Transplants may be preferred in sites with high weed pressure; transplants will establish better in these sites with adequate mulching and irrigation, if possible. Also, some sites with steep slopes may be easier to establish with transplants. Seed placed on sloped sites can wash away during heavy rains and make seeding with tractor or ATV equipment difficult. Similarly, rocky sites will make site preparation and seeding difficult. Plug planting may be an option in this scenario.

Some sites may already have some components of the native plant community that would be beneficial to be retained. In this condition, planting transplants may be preferred to preserve species already present. Some rarer forb species or species for which seed production is difficult may only be available as transplants. Planting transplants of these species would allow landowners to include these species in their planting. In addition, some species, such as slow-growing balsamroot, are difficult to establish from seed.

Before planting transplants remove the surface vegetation. Scalp each planting location with a hoe or shovel in a 1–2 ft diameter circle. Use a hoe, shovel, or planting bar to open a hole of the appropriate size for each plug, or container size. Mulching the surface around each plant location with wood chips (3 inches deep) will provide some weed control and result in better establishment. Avoid placing mulch on the base of transplants. Leave a 2-inch radius circle of unmulched soil around each transplant to prevent damage to the plants. Planting of woody plants, forbs, and grasses is best done in the fall before the soil freezes.

### *Seeding*

In most situations planting seed is the preferable method for establishing native forbs and grasses. Most forbs that are available by seed are easier and less expensive to establish by direct seeding compared to transplanting. There are several methods to disperse the seed, including broadcast or drill. Plant seed preferably in the fall from October to November, after frost and before the ground freezes. Wait at least 72 hours after the last herbicide treatment before seeding a native forb mix.

### *Drill seeding*

The preferable method for seeding natives is a seed drill. Seed drills use less seed than other methods and often result in better seed-to-soil contact. Seed rates using a no-till drill are usually about half the rate used for broadcast seeding. Many areas in and around remnant oak plant communities may not be accessible by a tractor and seed drill. Drill seed (preferably with a no-till drill or range drill) into the prepared seed bed, ideally just before the fall rains. Add a seed bulking agent to help seeds evenly flow through the seed drill. Seeds can be mixed and bulked up with an inert carrier ingredient such as rice hulls. Use two to three parts of bulking agent for each part seed by volume.

### *Broadcast seeding*

Broadcast seeding methods may offer more flexibility in maneuverability and practicality in and around remnant oak stands. This method may be preferable in areas inaccessible to tractors, with rocky soils, or sites too small to be practical with a seed drill. Seeds can be broadcast with a handheld (belly grinder) or ATV-mounted broadcaster, or spread by hand. Seed mixes should be bulked up with an inert carrier ingredient such as sand, fine-grained vermiculite, clay-based kitty litter, gypsum, or polenta (coarse cornmeal). Use two to three parts of bulking agent for each part seed by volume and mix thoroughly. These inert carriers help improve the seed distribution across a site, while also providing visual feedback on where seed has been thrown. Seed can be hand broadcast (similar to scattering poultry feed). When hand broadcasting, divide the seed into at least two batches, bulk the seed mix with an inert carrier, and sow each batch separately. Scatter the first batch evenly over the site while walking in parallel passes across the site. Then to ensure the seed is evenly distributed, walk perpendicular to the previous passes to scatter the second batch.

## Maintenance

Maintenance is critical to the success of wildlife habitat plantings. Control weeds around the planting to prevent reseeding of weeds for the first two years. Maintenance practices must be adequate to control noxious and invasive species and may involve methods such as string trimming, hand hoeing, or careful spot spraying with herbicides. Seeded habitat typically does not need irrigation to establish successfully. If transplants are used, irrigation may be needed the first year after planting especially in a dry year. Monitor for rodents, deer, or other animal damage and install protection if necessary.

During the establishment period, it is important to provide:

ö Protection from deer, elk and rodents with tree tubes, or cages. Fencing areas may be necessary to exclude grazing or browsing animals.

ö Weed control is critical in the first and second years after planting. If the site is well prepared, then less effort will be required for weeding after project installation. Maintenance practices must be adequate to control noxious and invasive species and may involve methods such as mowing, string trimming, hand hoeing, or spot spraying with herbicides. Weeds should be prevented from going to seed in, or adjacent to, the planting during the first two (and possibly three) years after planting to help ensure long-term success. Familiarity with the life cycle of on-site weeds will facilitate appropriate timing of management activities.

Arrowleaf balsamroot (*Balsamorhiza sagittata*) in an oak savanna at Memaloose Overlook (photo: Matthew Shepherd).

Common weed-management strategies include:

- Spot spraying: Spot spraying with herbicides can be effective, relatively inexpensive, and require minimal labor, even on larger project areas. Care should be taken that herbicides do not drift or drip onto desirable plant species.

- Selective herbicides: Grass-selective herbicides can be used to control weedy grasses. Contact a local crop advisor or Extension specialist for appropriate herbicide selection and timing or refer to the resources in the site preparation and planting resources listed below.

- Mowing/string trimming: Mowing or string trimming can be utilized to keep weedy species from going to seed.

- Hand weeding: Hand weeding (including hoeing) can be effective in small areas with moderate weed pressure.

## Resources

### Plant Identification

- *Flora of the Pacific Northwest: An Illustrated Manual.* (2018, 2nd ed.; Leo Hitchcock and Arthur Cronquist.) Seattle: University of Washington Press.

- *Handbook of Northwestern Plants.* (2001; Helen Gilkey, La Rea Dennis, and L. D. Johnston.) Corvallis: Oregon State University Press.

- *Plants of Southern Interior British Columbia and the Inland Northwest.* (1999; Ray Coupe, Dennis Loyd, and Roberta Parish.) Vancouver, BC: Lone Pine Publishing.

- *Wildflowers of the Columbia River Gorge: A Comprehensive Field Guide.* (1988; Russ Jolley.) Portland: Oregon Historical Society Press.

- *Wildflowers of the Pacific Northwest.* (2006; Mark Turner and Phyllis Gustafson.) Portland, OR: Timber Press.

- *A Manual of the Higher Plants of Oregon.* (1961; Morton E. Peck.) Hillsboro, OR: Binfords & Mort Publishers.

### Site Preparation and Native Planting

- Xerces Organic Site Preparation Methods: xerces.org/publications/guidelines/organic-site-preparation-for-wildflower-establishment

- *PNW Weed Management Handbook*: pnwhandbooks.org/weed

- *Shrub Steppe and Grassland Restoration Manual for the Columbia River Basin*. (2011; J. E. Benson, R. T. Tveten, M. G. Asher, and P. W. Dunwiddie.) wdfw.wa.gov/publications/01330

Table 2. Regional native seed vendors and plant nurseries

| SEED VENDORS | | |
|---|---|---|
| BFI Native Seeds<br>https://www.bfinativeseeds.com/<br>1145 S Jefferson Ave<br>Moses Lake, WA 98837<br>Matthew Benson<br>ph: (509) 765-6348<br>fax: (509) 764-9978<br>mbenson@bfinativeseeds.com | L&H Seeds Inc.<br>http://www.lhseeds.com/<br>3930 Moon Rd<br>Connell, WA 99326<br>Damon Winter<br>ph: (509) 234-4433<br>fax: (509) 234-0202<br>info@lhseeds.com | Heritage Seedlings<br>http://www.heritageseedlings.com<br>4194 71st Ave SE<br>Salem, OR 97317<br>Lynda Boyer<br>ph: (503) 585-9835<br>fax: (503) 371-9688<br>sales@heritageseedlings.com |
| **PLANT NURSERIES** | | |
| Derby Canyon Natives<br>http://www.derbycanyonnatives.com/<br>9750 Derby Canyon Rd<br>WA 98847<br>PO Box 185<br>Peshastin, WA 98847<br>Mel Asher<br>ph: (509) 240-9792<br>mel@derbycanyonnatives.com | Humble Roots Farm and Nursery LLC.<br>https://www.humblerootsnursery.com/<br>Mosier, OR 97040<br>Kristin Currin and Andrew Merritt<br>ph: (503) 449-3694<br>humbleroots@gorge.net | |

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# Protecting Bees from Pesticides in Oregon Cherry Orchards

Top to bottom—An *Andrena* mining bee visits a cherry bloom; pollinator habitat in a cherry orchard; an *Agapostemon* bee visits pollinator habitat planted next to a cherry orchard in Oregon (photos: Xerces Society / Sarah Foltz Jordan; Oregon State University / Emily Carlson).

Good pollination is critical to Oregon tree fruit production. Managed honey bees (*Apis mellifera*) and native bees living around orchards, including bumble bees, mason bees, and mining bees, are important pollinators of commercial cherries and other fruit crops. Maintaining abundant, diverse, and healthy pollinator populations is critical for pollination success and setting a large, marketable crop of cherries. Growers can take steps to support pollinators in and around orchards by providing habitat and using a combination of management and mitigation strategies to reduce pollinator exposure to pesticides.

Research conducted by Oregon State University in 2020–21 detected a variety of pesticides in pollen collected by honey bees in and around cherry orchards in The Dalles and Hood River, including some at levels that could be harmful to honey bee health. Pollen samples were collected from hives in orchards during bloom through petal fall, and again after bloom. The researchers identified the pollen to plant type where possible and found that the bees were collecting pollen from cherry and other tree fruit, understory plants, mustard cover crops, and wildflowers outside of the orchards at different times during the season.

Pesticides detected at levels that can be harmful to honey bee health in samples collected from cherry bloom through petal fall included pyridaben (e.g., Nexter), bifenthrin (e.g., Brigade), tolfenpyrad (e.g., Bexar), and carbaryl (e.g., Sevin). After bloom, high-hazard pesticide detections in bee-collected pollen included bifenthrin (e.g., Brigade), chlorantraniliprole (e.g., Altacor), imidacloprid (e.g., Admire), and tolfenpyrad (e.g., Bexar). Some of these pesticides were likely applied in cherry orchards, while others may have been applied and picked up by honey bees elsewhere in the landscape. For more detail on the possible sources of these residues, see Table 1 (page 5).

In addition to the individual high-hazard detections, many pollen samples contained combinations of different pesticides that can interact to jointly increase toxicity to bees. Most of these synergistic interactions occur between certain

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common groups of fungicides and insecticides, such as DMI fungicides and pyrethroids or neonicotinoids. For examples of the synergistic interactions detected in pollen samples, see Table 2 on page 9.

These pesticide detections underscore the importance of taking precautions to better protect bee health in and around orchards. In some cases, pesticide label restrictions may not be protective enough for bee health, and growers may need to go beyond the label to reduce the use and off-target drift of bee-toxic pesticides in order to ensure the health of pollinator populations and continued crop pollination success. This factsheet outlines the key elements of pesticide risk for pollinators, summarizes results and takeaways from the recent Oregon State University cherry research, and provides actionable steps for growers to better protect pollinators from pesticides around cherry bloom.


A cherry orchard site in Oregon where pollen samples were collected for identification and pesticide residue analysis (photo: Oregon State University / Emily Carlson).

## Pesticide Risk to Pollinators

### What types of pesticide applications are high risk for pollinators?

Some pesticide applications pose a greater risk than others for pollinators. The risk of a pesticide depends on how harmful it is to bees (its toxicity), and the dose that bees receive (also called exposure). Highly bee-toxic, environmentally persistent, and systemic chemicals are more likely to lead to harmful exposures. In other words, if a pesticide is very toxic, sticks around in plants, soil, and water for a long time, and/or can be taken up into plants' pollen and nectar, bees are more likely to encounter a harmful dose.

There are a variety of resources available to look up the toxicity of different pesticides to honey bees, including the online UC IPM Bee Precaution Pesticide Ratings tool and the rankings table in the PNW Extension publication, How to Prevent Bee Poisoning from Pesticides. Residual toxicity, or how long residues remain toxic to bees after application, is also important for determining pesticide risk. The U.S. Environmental Protection Agency maintains a table of the currently available information on residual toxicity to honey bees (Residual Time to 25% Bee Mortality). While there is considerable variation in residual toxicity due to differences in formulations, application rates, and crops, this limited dataset can still offer a general understanding of how long different pesticides may remain toxic to bees after application (e.g., 3 hours vs. 60 hours).

### Where and how bees are exposed?

Most bees roam farther than a single orchard. While small native bees may only fly a few hundred feet away from their nest, managed honey bees can travel up to several miles from their hive looking for high-quality food resources. This wide flight range means that pesticides applied in far-off fields, orchards, and backyards can affect the health of bees in our own orchards, and our pest management activities can affect bees living elsewhere in the community.

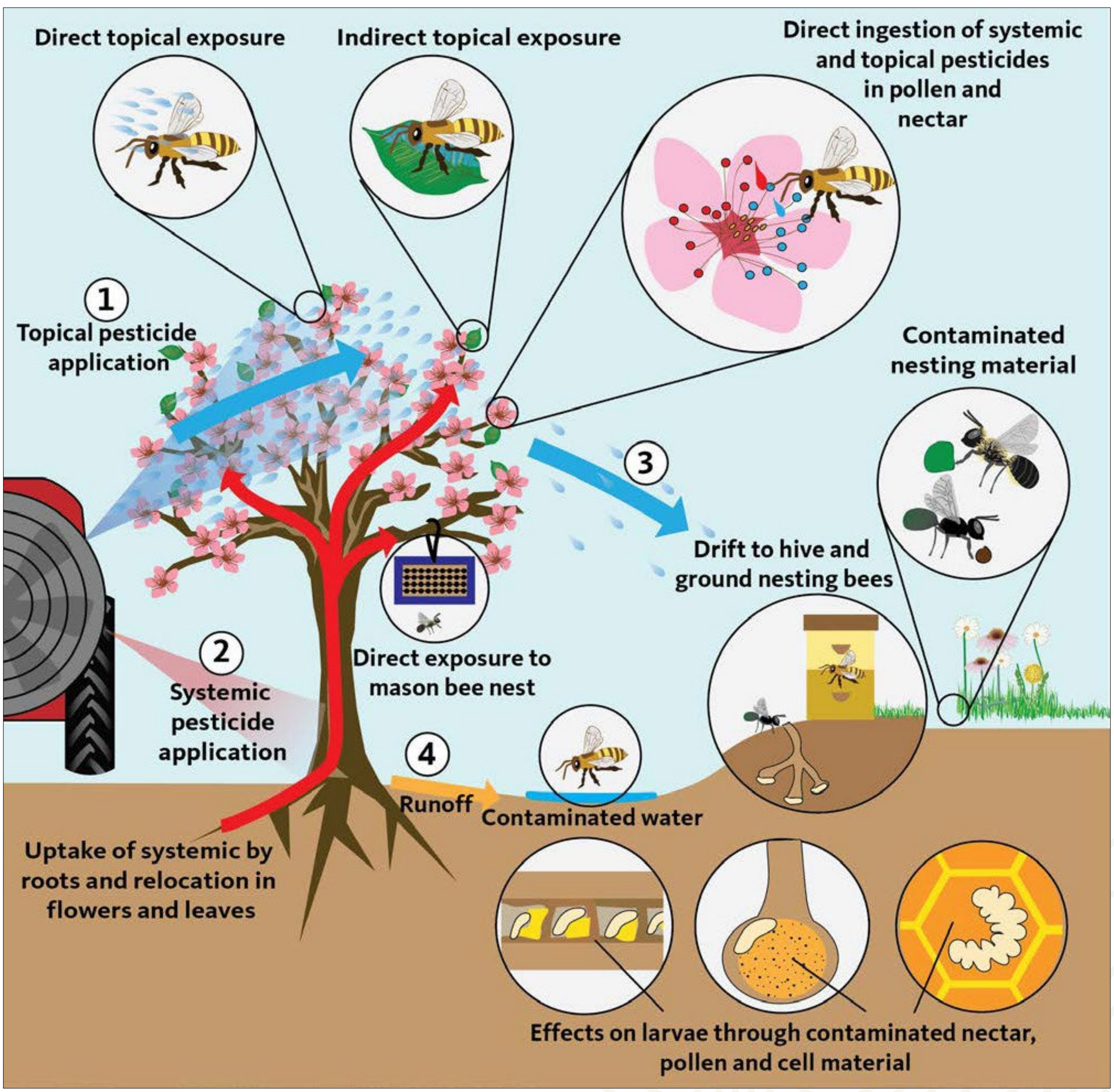
Bees can be exposed to pesticides directly if they are applied when bees are active, or to residues on leaves or in the pollen and nectar of flowers they visit, including crop flowers and flowering weeds in the understory and margins. Pesticides applied end up in soil, where most native bees build their nests. Mason bees, which build their nests in hollow stems, collect mud to make walls inside their nests. Contaminated soil is an important route of exposure to pesticides for native bees.

Pesticides can move away from where they are sprayed, including drift through the air, runoff across the soil surface, and leaching into soil and groundwater. Only about one-third to two-thirds of pesticides applied by airblast sprayers reach the orchard canopy, with the rest drifting to the ground or other off-target locations (Hulbert et al. 2020; Vercruysse et al. 1999). Bees can encounter pesticides in flowering weeds in and around crop fields, as well as in contaminated soil and water.

All of the pesticides listed were detected in honey bee-collected pollen samples at Hazard Quotients (HQ) above 500. HQs of these levels are associated with colony losses and other individual and colony health impacts, such as honey bee queen death or replacement in managed colonies (Traynor et al. 2016). For more information on HQs, including how they are calculated and their value for assessing pesticide hazards to honey bees, see Carlson et al. (2022)and Stoner & Eitzer (2013).

## Figure 1. Pollinators such as bees can be exposed to pesticides in multiple ways:

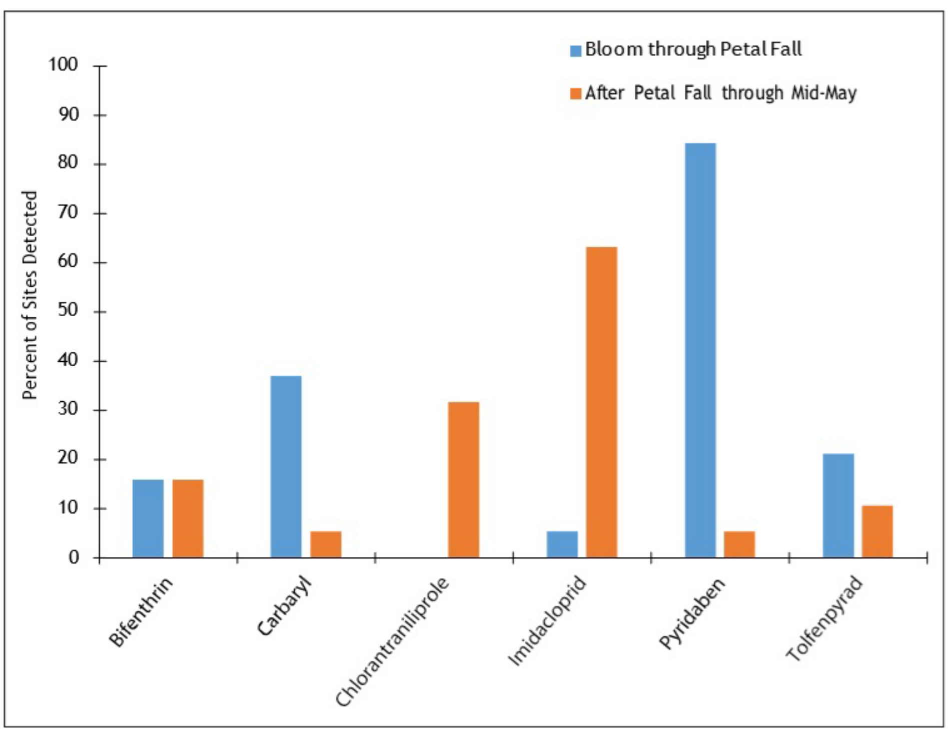
(1) direct contact with pesticides or pesticide residues that remain active on foliage and flowers, (2) in nectar and pollen for systemic pesticide treatments that are drawn up through a plant's vascular system, (3) pesticide drift into areas where bees are foraging, nesting or gathering nesting material, and (4) pesticide runoff that contaminates water that bees forage on or the nesting beds of ground-nesting bees (figure: Oregon State University / Iris Kormann and Andony Melathopoulos).



Honey bee hives were placed in a blooming cherry orchard, with pollen traps installed at the hive entrances to capture pollen loads from the bees as they returned from foraging. Pollen loads collected from the traps over a 24 hour period were taken to a research laboratory for pollen identification and pesticide residue analysis (photos: Oregon State University / Emily Carlson).

## Figure 2. The percentage of sites where the highest hazard pesticides were detected in honey bee-collected pollen during cherry bloom.

Residues were sampled from 19 cherry orchard sites located throughout the major cherry production regions of The Dalles and Hood River in Oregon.



## Table 1. Pesticide residues and possible sources.

Several insecticides were detected at levels that can be harmful to honey bee health in pollen collected by honey bees during cherry bloom and petal fall, as well as after bloom, continuing through the end of sampling in mid-May.

### Timing of Detections: Crop Bloom Through Petal Fall

| PESTICIDE | POLLEN SOURCE | POSSIBLE RESIDUE SOURCES BASED ON LABELED USES |
|---|---|---|
| **Bifenthrin (e.g., Brigade, Sniper)** | Tree fruit* | Bifenthrin has no labeled uses in production cherry orchards, suggesting that the likely source of these residues was drift from applications in other nearby crops. |
| **Carbaryl (e.g., Sevin)** | Unspecified (mix of pollen sources) | Because carbaryl is prohibited from being applied to blooming crops, possible sources include:<br>• Popcorn or petal fall applications in cherry orchards to control aphids, leafrollers, or bud moths.<br>• Drift from pre-bloom applications in nearby apple or pear orchards. |
| **Pyridaben (e.g., Nexter)** | Tree fruit*, understory plants, wildflowers | With a 300-day preharvest interval in cherries, pyridaben should not be applied to bearing cherry orchards anytime near bloom. Therefore, the residues likely originated from applications to other nearby crops. Possible sources:<br>• Drift from pre-bloom applications in apple and/or pear orchards targeting aphids, leafrollers, mites, and pear psylla.<br>• Honey bee visitation to early blooming pear orchards treated with pyridaben for pear psylla control. |
| **Tolfenpyrad (e.g., Bexar)** | Tree fruit*, understory plants, wildflowers | • Bloom and petal fall applications to control black cherry aphids or thrips in cherry orchards.<br>• Drift from applications to nearby crops, such as pre-bloom applications in pear orchards to control pear rust mites or pear psylla. |

### Timing of Detections: After Petal Fall

| PESTICIDE | POLLEN SOURCE | POSSIBLE RESIDUE SOURCES BASED ON LABELED USES |
|---|---|---|
| **Bifenthrin (e.g., Brigade, Sniper)** | Mustard cover crop, wildflowers | Bifenthrin has no labeled uses in production cherry orchards, suggesting that the likely source of these residues was drift from applications in other nearby crops. |
| **Chlorantraniliprole (e.g., Altacor, Dauntless)** | Wildflowers | • Drift from petal fall applications aimed at controlling aphids, leafrollers, or thrips in cherry orchards.<br>• Drift from pre-bloom or bloom applications in other nearby crops. |
| **Imidacloprid (e.g., Admire Pro, Macho)** | Mustard cover crop, wildflowers | • Drift from petal or shuck fall applications in cherry orchards to control aphids or leafhoppers.<br>• Drift from spring applications targeting cherry fruit fly.<br>• Drift from applications to nearby crops, such as petal fall applications in pear orchards for pear psylla control. |
| **Tolfenpyrad (e.g., Bexar)** | Mustard cover crop | • Drift from applications for cherry fruit fly in cherry orchards.<br>• Drift from applications targeting a variety |

*TREE FRUIT POLLEN COULD NOT BE IDENTIFIED TO CROP SPECIES. HOWEVER, TREE FRUIT POLLEN WAS ONLY IDENTIFIED IN SAMPLES TAKEN DURING CHERRY BLOOM THROUGH PETAL FALL, SO WHILE MOST OF THESE SAMPLES WERE LIKELY COLLECTED BY HONEY BEES FORAGING ON CHERRY FLOWERS, SOME OF THE POLLEN MAY HAVE COME FROM EARLY BLOOMING PEAR TREES IN THESE REGIONS.

## How to Protect Pollinators During and Beyond Bloom

### Use integrated pest and pollinator management (IPPM).

Integrated pest and pollinator management (IPPM) is a strategy that focuses on the long-term prevention of crop pests and diseases through a combination of techniques such as biological control, habitat manipulation, cultural practices, and use of resistant varieties. Pesticides are reserved as a final line of defense, only to be applied when established guidelines justify their necessity to prevent economic damage. Following an IPPM approach can help to reduce pesticide costs and inputs, which in turn will help pollinators and other beneficial insects in and around your orchard to thrive.

### Pesticide Detections in Hood River

While most pollen samples in this project were taken from cherry orchards during and after bloom in The Dalles, samples were collected at three sites during bloom in Hood River in 2020. All Hood River samples had high levels of pyridaben (e.g., Nexter). Notably, pyridaben (Nexter® SC) is labeled for use for control of pear psylla nymphs during pear bloom with a 24(c) Special Local Needs label in Oregon, at a rate of up to 0.73 lb ai/acre, if applied between late evening and early morning. While honey bees are often more frequent visitors to apple and cherry orchards, they will visit pear flowers to collect pollen (Diaz et al. 2013). Pear orchards are the most likely source of this pesticide in bee-collected pollen in Hood River.

- Always use appropriate scouting, monitoring, and/or degree day models to confirm that economic thresholds have been met before making a pesticide application.
- Be proactive to identify and use prevention-based management strategies for pests and diseases of concern.
- For more detailed guidance on pest monitoring, economic thresholds, and prevention-based strategies, refer to the Pacific Northwest Pest Management Handbook for Cherry.

### Avoid bloom applications wherever possible, especially of combinations of pesticides that jointly increase toxicity to bees.

- Insecticide applications during bloom can result in high exposure for pollinators in pollen and nectar. Some insecticides are allowed to be applied during crop bloom if beekeepers are notified and spraying occurs when bees are less active (i.e., after dark). While this will avoid the maximum exposure to bees from direct knockdown of actively flying insects, even relatively short residual pesticide products are likely to be picked up on open flowers in the days following the nighttime application.
- Fungicides can have subtle harmful effects on pollinators, including making bees more vulnerable to other stressors like pathogens and diseases. Fungicides can also increase the bee toxicity of some other pesticides that may be present in or around the orchard at the same time. Bloomtime fungicide applications are often unavoidable in tree fruit management, so care should be taken to avoid tank mixtures of insecticides, miticides, and fungicides with synergistic toxicity, as bees exposed to common fungicides become more vulnerable to these other pesticide exposures. Synergistic interactions are not exclusively caused by pesticide tank mixtures. Multiple pesticide applications, leading to overlapping exposures to co-synergistic pesticides, can also increase bee toxicity. Consider the residual toxicity times of the products you are using and avoid applying a potentially synergistic pesticide when residues of co-synergists may still be present in the orchard. For more information on pesticide residual toxicities for bees, refer to the EPA webpage on Residual Time to 25% Bee Mortality (RT25) Data. For examples of combinations of pesticides used in cherry orchards that may result in synergistic interactions, see Table 2 (page 9).

### Use care with pre-bloom and petal fall applications.

- Pollinators begin exploring orchards in search of open flowers well before peak bloom, and continue seeking nectar and pollen through petal fall, until the last open flowers are gone. To minimize pollinator exposure, apply pesticides as early as possible for pre-bloom spraying and as late as possible for petal fall spraying. Always ensure that pesticide applications and timing are justified based on scouting and monitoring.

### Maintain good communication with beekeepers and neighbors.

ö Building and maintaining a strong relationship with your beekeeper is essential for a successful tree fruit operation, and the cornerstone of that relationship is open and effective communication.

ö Several fungicides commonly used during orchard bloom can interact with miticides, like amitraz and tau-fluvalinate, frequently applied by beekeepers to manage *Varroa* mites in their hives. These synergistic interactions can significantly increase the toxicity of these chemicals for honey bees. Both growers and beekeepers should be made aware of this risk and, whenever feasible, take measures to avoid exposing bees to residues of both chemicals simultaneously. Achieving this goal will require comprehensive education and effective communication between both parties.

ö Remember that farms exist within larger ecosystems, where everything is connected. Therefore, building good relationships with your neighbors is crucial, as actions on your neighbor's property can impact your bees, and vice versa. Even when your orchards are not in bloom, take extra precautions when applying pesticides to avoid them drifting onto your neighbor's land and harming their bees. Talk to your neighbors about doing the same. Working together, we can all help support healthy bee populations and keep our farm landscapes thriving.

### Provide flowering habitat for pollinators outside of orchards.

ö Providing pollinators with a variety of flowering resources can help improve their health and nutrition. Healthy pollinators are often more resilient to stressors, including exposure to parasites, diseases, and low levels of pesticide residues. These habitats can also provide other essential resources such as nesting sites and materials that help support native pollinator populations. By establishing pollinator-friendly habitats around your orchard and taking precautions to protect them from pesticide drift and contamination, you can provide significant benefits to your local pollinator community.

ö For specific guidance on how to create and maintain pollinator habitat around your orchard, see the Xerces Society Enhancing Pollinator Habitat in Remnant Oak Plant Communities Factsheet.

## Reduce Pesticide Drift and Off-Site Movement

Many of the pesticide residues detected in pollen collected by honey bees in and around cherry orchards in The Dalles and Hood River likely originated as drift from nearby applications to other crops. When applying pesticides, take steps to minimize pesticide drift. The amount of drift is determined by numerous factors, including spray droplet size, application rate, environmental conditions such as wind speed/direction and relative humidity, equipment type and settings, and operator care and experience. Deliberate attention should be given to each of these factors before making a pesticide application.

### Avoid applying pesticides to or allowing drift onto flowering plants, including weeds.

ö Take precautionary measures to prevent pesticides from drifting onto noncrop flowers within and surrounding the orchard, including flowering weeds in the understory or margins, and any flowering resources in adjacent pollinator or remnant habitats.

ö If flowering weeds are present in orchard rows or margins, mow them down before applying pesticides to the crop.

ö When making a pesticide application, turn off your spray equipment when you reach the end of a row.

ö Establish an unsprayed buffer around any sensitive areas surrounding your orchard, such as designated pollinator habitat or remnant natural/seminatural habitats. The wider the buffer you are able to provide, the greater the benefits that habitat will yield for pollinators, beneficial insects, and other wildlife.

## Only apply pesticides in optimal environmental conditions.

- Wind speed and direction are two of the primary factors that determine how much pesticide moves away as drift, and where it is deposited. Only apply when wind speeds are between 2–10 mph. Do not apply during temperature inversions, when pesticides are more likely to move off-site.
- Note: Temperature inversions are most common between late afternoon and early morning. If you are planning to make a nighttime application, always check if an inversion exists before applying. More information on how to recognize temperature inversions can be found in this BASF Technical Information Bulletin.

## Consider using drift-reduction techniques, products, and equipment.

- Your equipment settings can substantially impact the drift risk of your application. Always adjust spray nozzles to the largest droplet size recommended on the product label. Additionally, when using an air-assisted sprayer, carefully adjust fan settings such as speed, blade pitch, air outlet width, and gearbox position to minimize drift beyond the tree canopy.
- There are also various products and technologies that have been developed to enhance pesticide deposition rates and reduce pesticide drift. For orchard production, these include drift-reduction nozzles, electrostatic sprayers, sensor-based spray equipment, and drift-control adjuvants.
- Drift-reduction nozzles, such as air-induction (aka Venturi) and turbulence chamber (aka pre-orifice) nozzles, can help minimize pesticide drift and off-target deposition by enlarging spray droplet size without increasing product volumes. These nozzles have been reported to reduce pesticide drift by up to 50% (Torrent et al. 2020).
- Electrostatic spray systems use static electricity to electrically charge spray droplets, which then become attracted to oppositely charged leaves. This attraction enables the droplets to overcome gravity, enhancing pesticide deposition and minimizing drift. However, the specific design and settings of the sprayer significantly influence the drift reduction benefits of these systems (Salcedo et al. 2023). Additionally, because many electrostatic sprayers produce very fine spray droplets, it's advisable to exercise extra caution when operating them, especially in windy conditions.
- Sensor-controlled spray equipment has been around since the 1980s. However, recent technological advancements have significantly improved their sophistication, reliability, and drift-reduction potential. Modern models of 'variable spray rate' applicators, including ultrasonic, LiDAR, and image-responsive sensor sprayers, can adjust spray outputs for each nozzle, based on the detected crop canopy characteristics. These advanced applicators can not only lower spray volumes, but also substantially reduce pesticide drift with ground drift reductions of 60–85% and airborne drift reductions of 80–90% (Salcedo et al. 2021; Xun et al. 2023).
- Drift control adjuvants can be extremely effective at reducing pesticide drift, with some formulations showing up to a 60% decrease in ground drift potential and an 85% reduction in airborne drift potential (Itmec et al. 2022). However, the absence of federal regulation for these adjuvants raises concerns about their potential toxicity to pollinators. Several spray adjuvants have been found to increase the toxicity of tank-mixed insecticides to bees (Mullin 2015; Mesnage & Antoniou 2017). Additionally, some adjuvants can negatively impact bees by impairing their learning ability and increasing their susceptibility to viral diseases (Ciarlo et al. 2012; Mullin et al. 2016; Fine et al. 2017).
- Note - Hooded or shielded spray equipment, such as full boom shields, nozzle shields, tunnel sprayers, and recycling tunnel sprayers, can also be used to substantially reduce drift from pesticide applications in other cropping systems, including row crops and vineyards.

## Regularly maintain and calibrate spray equipment.

- Regular maintenance and calibration of spray equipment is crucial for ensuring accurate and effective distribution of pesticides onto their intended targets. This not only enhances pest control efficacy and cost-effectiveness, it also helps minimize pollinator exposure to pesticides by reducing over-application, off-target deposition, and drift.

## Use windbreaks and other vegetative barriers to reduce drift and protect habitat outside of orchards.

- Wind breaks and other vegetative barriers can be used to reduce pesticide drift in your orchard. Planting windbreaks upwind of your orchard can decrease wind speeds within the orchard, thus reducing the amount of drift generated by any pesticide applications. Conversely, planting vegetative barriers downwind of your orchard can capture excess airborne spray particulate from applications, preventing pesticide droplets from drifting beyond your orchard area.
- Vegetative barriers can also be planted in between your orchard and any nearby pollinator or remnant natural/ seminatural habitats to help protect these areas from pesticide drift by intercepting pesticide particulate.

## Table 2. Examples of pesticide combinations that may result in synergistic interactions based on their mode of action groups.

This table is not meant to serve as a comprehensive list of all known and potential synergisms that may occur in tree fruit crops in Oregon. Only pesticides that were detected in the pollen residue analysis or are labeled for use in cherry production were included. There are other combinations of pesticides, including insecticide–insecticide, insecticide–miticide, and fungicide–fungicide interactions, that may also result in synergism.

| FUNGICIDE MODE OF ACTION GROUP | FUNGICIDE ACTIVE INGREDIENTS (EXAMPLES) | | *INSECTICIDE/ MITICIDE MODE OF ACTION GROUP* | *INSECTICIDE/MITICIDE ACTIVE INGREDIENTS (EXAMPLES)* |
|---|---|---|---|---|
| 1 (MBC Fungicides) | - Thiophanate-methyl (e.g., Incognito, Talaris, Topsin) | + | 3A (Pyrethroids) | • Bifenthrin (e.g., Brigade, Sniper) |
| | | | 4A (Neonicotinoids) | • Acetamiprid (e.g., Assail, Intruder) |
| | | | | • Clothianidin (e.g., Arena, Belay) |
| | | | | • Imidacloprid (e.g., Admire Pro, Macho) |
| 3 (DMI Fungicides) | -Difenoconazole (e.g., Inspire, Miravis Duo, Quadris Top)<br>-Fenbuconazole (e.g., Indar)<br>-Myclobutanil (e.g., Eagle, Rally)<br>-Propiconazole (e.g., Concert II, Quilt Xcel, Tilt)<br>-Tebuconazole (e.g., Luna Experience, TebuStar)<br>-Triflumizole (e.g., Procure, Trionic) | + | 3A (Pyrethroids) | • Bifenthrin (e.g., Brigade, Sniper) |
| | | | 4A (Neonicotinoids) | • Acetamiprid (e.g., Assail, Intruder) |
| | | | | • Clothianidin (e.g., Arena, Belay) |
| | | | | • Imidacloprid (e.g., Admire Pro, Macho) |
| | | | 4D (Butenolides) | • Flupyradifurone (e.g., Sivanto)* |
| | | | 15 (Benzoylureas) | • Dimethenamid (e.g.,FreeHand, Tower, Verdict) |
| | | | 28 (Diamides) | • Chlorantraniliprole (e.g., Altacor, Dauntless) |
| 7 (SDHI Fungicides) | -Boscalid (e.g., Pageant, Pristine) | + | 4A (Neonicotinoids) | • Acetamiprid (e.g., Assail, Intruder) |
| | | | | • Clothianidin (e.g., Arena, Belay) |
| | | | | • Imidacloprid (e.g., Admire Pro, Macho) |
| 11 (QoI Fungicides | -Azoxystrobin (e.g., Abound, Quadris, Quilt Xcel)<br>-Pyraclostrobin (e.g., Cabrio, Pristine)<br>-Trifloxystrobin (e.g., Flint, Gem, Luna Sensation) | + | 3A (Pyrethroids) | • Bifenthrin (e.g., Brigade, Sniper) |
| | | + | 21A (METI Acaricides) | • Fenpyroximate (e.g., FujiMite) |
| | | | | • Pyridaben (e.g., Nexter) |
| | | | | • Tolfenpyrad (e.g., Bexar) |

## Synergistic Interactions: How Combinations of Pesticides Can Increase Toxicity to Bees

Several fungicides commonly applied during tree fruit bloom are known to interact with various insecticides and miticides, creating a combined toxicity greater than the sum of their individual toxicities. This phenomenon, known as synergistic interaction, substantially increases the risk these pesticides pose to bees.

Pesticide residues were detected in 79% of pollen trap samples collected between cherry bloom and mid-May. Among samples with detectable residues, nearly half contained combinations of residues that could result in synergistic interactions, substantially increasing their risks to bees. About a quarter of these samples were collected during cherry bloom and three-quarters post-bloom. In the most extreme case, a single sample contained residues from nine different pesticide co-synergists, forming four distinct combinations of synergistic modes of action and raising concerns about unpredictable increases in toxicity.

## Conclusions

Hazardous levels of several individual pesticides and pesticide combinations were detected in pollen collected by honey bees during and after cherry bloom in Hood River and The Dalles. These high pesticide loads are associated with colony losses and other individual and colony health impacts, such as honey bee queen death or replacement in managed colonies (Traynor et al. 2016).

The findings from this project indicate that current mitigations and label language may not be enough to provide sufficient protections to bees for some applications. For example, high levels of pyridaben (e.g., Nexter) and tolfenpyrad (e.g., Bexar) were detected in tree fruit pollen. Current label guidelines permit the application of these pesticides during crop bloom, so long as certain conditions are met, such as ensuring that the product is applied at least 8 hours prior to bee foraging and sending notice of the application to your bee broker. However, the residues can remain toxic to honey bees for longer than 8 hours. Growers should reconsider their use of these and similar extended residual insecticides during crop bloom, and outside of this period, applicators should take additional precautions to prevent drift onto flowering resources in the surrounding landscape.

While managed honey bees are often relocated from orchards after the bloom period, native pollinators and other beneficial insects that offer essential pollination and pest control services remain present throughout the entire season. Therefore, it is important to take precautions to safeguard these insects and reduce pesticide drift, even when the orchard is not in bloom.

In many cases, treatments for economically damaging diseases, such as brown rot blossom blight, during cherry bloom may be unavoidable. Therefore, whenever possible, producers should take care to refrain from applying insecticides and miticides in the orchard when residues of these fungicide synergists are likely to be present. Likewise, it is advisable to avoid applying pesticide tank mixtures, especially of known synergistic combinations.

Many of the pesticide residues found at highly hazardous levels in pollen collected by honey bees likely originated as drift from nearby or neighboring applications, which underscores the value in forming and maintaining good relationships and open lines of communication with your neighbors, as their activities can significantly impact your operations, just as yours can affect theirs.

## Additional Resources

- *Oregon Bee Guide*. (2017; S. Kincaid.) Oregon Department of Agriculture. oregon.gov/oda/shared/Documents/Publications/IPPM/ODABeeGuide.pdf
- *How to Prevent Bee Poisoning from Pesticides*. (2016; L. Hooven, R. Sagili, and E. Johansen.) Oregon State University Extension. extension.oregonstate.edu/catalog/pub/pnw-591-how-reduce-bee-poisoning-pesticides
- *Preventing Water Contamination and Pesticide Drift: A Checklist for Pesticide Applicators*. (2023; T. Stock and S. Castagnoli.) Oregon State University Extension. extension.oregonstate.edu/catalog/pub/em8964-s
- *Minimizing Pesticide Risk to Bees in Fruit Crops*. (2015; E. May, J. Wilson, and R. Issacs.) Michigan State University Extension. canr.msu.edu/resources/minimizing_pesticide_risk_to_bees_in_fruit_crops
- *USDA Agronomy Technical Note 9: Preventing or Mitigating Potential Negative Impacts of Pesticides on Pollinators Using Integrated Pest Management and Other Conservation Practices*. (2014; M. Vaughan, G. Ferruzzi, J. Bagdon, E. Hesketh, and D. Biddinger.) United States Department of Agriculture, Natural Resource Conservation Service. xerces.org/publications/scientific-reports/preventing-or-mitigating-potential-negative-impacts-of-pesticides
- *Sprayers for effective pesticide application in orchards and vineyards (FABE-533)*. (2022; E. Ozkan and E. Gil.) Ohio State University Extension. ohioline.osu.edu/factsheet/fabe-533
- *Bee Precaution Pesticide Ratings*. (S. Dreistadt, E. L. Niño, L.G. Varela, E.C. Mussen, L. Hooven, B. Phillips, E. Johansen, T. Lawrence, and R. Sagili.) University of California Extension. Retrieved April 2024. ipm.ucanr.edu/bee-precaution-pesticide-ratings/
- *A Guide to Reducing Pesticide Risk to Bees in Tree Fruit Orchards*. (2023; M. Van Dyke, E. Mullen, D. Wixted, M. Centrella, and S. McArt.) Pollinator Network at Cornell University. cornell.app.box.com/v/ProtectionGuide-Orchard2023
- Residual Time to 25% Bee Mortality (RT25) Data. United States Environmental Protection Agency. www.epa.gov/pollinator-protection/residual-time-25-bee-mortality-rt25-data
- *Pacific Northwest Pest Management Handbook: Cherry*. (2023; A. Thompson, H. Stoven, and C. Adams.) Oregon State University, Washington State University, and University of Idaho Extension. pnwhandbooks.org/insect/tree-fruit/cherry
- Recognizing Temperature Inversions. (2017; BASF technical bulletin.) agriculture.mo.gov/plants/pdf/BASF_TechBulletin_TemperatureInversion_highres.pdf
- *Sensor Sprayers for Specialty Crop Production*. (2019; B. W. Warneke, J. W. Pscheidt, R. R. Rosetta, and L. L. Nackley.) Oregon State University Extension. extension.oregonstate.edu/catalog/pub/pnw-727-sensor-sprayers-specialty-crop-production
- *Selecting Spray Nozzles to Reduce Particle Drift*. (2017; T. Peters, A. Thostenson, J. Nowatzki, V. Hofman, and J. Wilson.) North Dakota State University Extension. www.ag.ndsu.edu/AgCMS/agmachinery/documents/pdf/selecting-drift-reducing-nozzles

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# Pollinator Cover Crops in Hazelnut Orchards

Top to bottom—*Halictus* bee on yarrow; crimson clover in hazelnut orchard; California poppies (photos: Sara Morris; Xerces Society / Mace Vaughan; Xerces Society / Eric Lee-Mäder).

Hazelnuts are commonly grown in the Willamette Valley with bare ground underneath the orchard. Bare ground is traditionally maintained in hazelnut orchards to allow for machine harvest. Young orchards are particularly susceptible to soil erosion because of a lack of cover and tree roots to help hold the soil. Cover crops or other plantings between the rows of hazelnuts can prevent soil erosion in addition to providing benefits for soil health, water infiltration, and beneficial insect conservation. Cover crops also can reduce soil compaction and allow growers to access the orchard to make applications during moist weather.

Although hazelnuts are wind-pollinated, and therefore, don't require pollinators to produce nuts, cover cropping can be designed to benefit pollination in nearby crops that do require insect pollination. In addition, these plantings could help local beekeepers and native bees that are lacking in forage resources, as well as important beneficial insects. Beneficial insects such as parasitoids and generalist predators like lacewings and lady beetles can benefit from floral resources (pollen and nectar) provided by some cover crops. These parasitoids and predators could help control filbertworms, leafrollers, and aphids, potentially reducing the need for some insecticide applications in hazelnuts.

## Selecting a Pollinator Cover Crop

There are several options for establishing ground cover that prevents soil erosion and provides habitat for pollinators and beneficial insects (see Table 1 for a list of species). Young orchards that are not being harvested have opportunities to grow many different plants in the alleys. Some growers choose to grow a crop that is harvested (alley cropping) such as grass seed, crimson clover, or even row crops such as strawberries. Annual cover crops such as clovers, vetch, and phacelia can provide habitat for pollinators and other beneficial insects. Some annual cover crops can reseed and grow in subsequent years but others may need to be replanted each year. For this reason, annual

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cover crops are easier to use in newly planted orchards before harvests have begun. Perennial cover crops can persist for many years and don't need to be replanted. Creeping red fescue can be used in hazelnuts to prevent erosion and has been used successfully in newly planted and mature hazelnut orchards. Creeping red fescue could be planted in combination with forbs that are beneficial for pollinators. Mixes of creeping red fescue and annual and perennial clovers and other flowering species are currently undergoing trials at the USDA Natural Resources Conservation Service (NRCS) Plant Materials Center (PMC) in Corvallis, Oregon, to evaluate their utility. One goal of the work at the NRCS PMC is to find species compatible with management in bearing hazelnut orchards, though this information could apply to non-bearing orchards as well.

Cover crops used in hazelnuts have to tolerate the production and harvest process. Hazelnuts are harvested off the orchard floor which requires preparation before harvest. Many orchards are flail mowed three times followed by leveling (scraping) to

## Table 1. Plants that can be used as pollinator-resource cover crops in hazelnut orchards.

| Common Name | Latin Name | Life History | Rate (LB/ ACRE)[1] | Potential Uses[2] | Shade Tolerance[3] |
|---|---|---|---|---|---|
| **Native Species** | | | | | |
| **Common yarrow** | *Achillea millefolium* | perennial | 0.5 | NBH, BH, FCH | moderate |
| **Menzies' fiddleneck** | *Amsinckia menzezii* | annual | 9 | NBH | low |
| **Farewell to spring[4]** | *Clarkia* sp. | annual | 2 | NBH | low |
| **Oregon sunshine** | *Eriophyllum lanatum* | perennial | 3 | NBH, BH, FCH | moderate |
| **California poppy[4]** | *Eschscholzia californic* | annual/ perennial | 5 | NBH, BH, FM | moderate |
| **Globe gillia[4]** | *Gilia capitata* | annual | 2 | NBH | low |
| **Douglas meadowfoam** | *Limnanthes douglasii* | annual | 20 | NBH, BH, FCH, FM | moderate |
| **Bicolor lupine** | *Lupinus bicolor* | annual | 20 | NBH, BH, FM | low |
| **Baby blue eyes** | *Nemophila menziesii* | annual | 8 | NBH, BH, FCH, FM | moderate |
| **Bristly phacelia** | *Phacelia nemoralis* | perennial | 3 | NBH, BH, FCH, FM | moderate |
| **Rosy plectritis** | *Plectritis congesta* | annual | 2 | NBH, BH | low |
| **Slender cinquefoil** | *Potentilla gracilis* | perennial | 2 | NBH, BH, FCH | moderate |
| **Selfheal** | *Prunella vulgaris* var. *lanceolata* | perennial | 4 | NBH, BH, FCH, FM | moderate |
| **Non-Native Species** | | | | | |
| **Five spot** | *Nemophila maculata* | annual | 20 | NBH, BH, FCH, FM | high |
| **Lacy phacelia[4]** | *Phacelia tanacetifolia* | annual | 9 | NBH, BH | low |
| **Balansa clover** | *Trifolium michelianum* | annual | 8 | NBH, BH, FCH, FM | moderate |
| **Arrowleaf clover** | *Trifolium vesiculosum* | annual | 15 | NBH, BH, FM | low |
| **Common vetch** | *Vicia sativa* | annual | 60 | NBH, BH, FCH | high |
| **Hairy vetch[4]** | *Vicia villosa* | annual | 40 | NBH, BH | low |

THIS TABLE INCLUDES GENERAL SUGGESTIONS FOR LIKELY USES. MANY OF THESE SPECIES ARE STILL BEING EVALUATED FOR THEIR SUITABILITY FOR USE IN HAZELNUT SYSTEMS. SOME PLANTS MAY PRODUCE RESIDUE OR STUBBLE THAT MAY AFFECT HAZELNUT HARVEST.

1 RATES ARE FOR BROADCAST SEEDING OF A SINGLE SPECIES, REDUCE THE RATE WHEN PLANTING IN A MIX.

2 NBH = NON-BEARING HAZELNUTS; BH = BEARING HAZELNUTS; FCH = FULL CANOPY HAZELNUTS; FM = FESCUE MIXES.

3 MODERATE OR HIGH SHADE TOLERANCE PLANTS MAY SURVIVE IN MATURE ORCHARDS WITH A FULL CANOPY.

4 THESE SPECIES WERE TESTED FOR HERBICIDE TOLERANCE. SEE TABLE 2 OPPOSITE FOR THE DETAILS ON HERBICIDE TOLERANCE.

prepare for harvest. Alternatively, some orchards are just flail mowed three times low enough to allow for harvest equipment to pick up the nuts. Some growers have established creeping red fescue cover and have successfully harvested by preparing for harvest with flail mowing only. It is important to select cover crops that do not produce excessive residue or thatch that will contaminate or impact the ability to harvest nuts off the floor. Pollinator cover crops are currently being evaluated for thatch/residue in trials at the NRCS Plant Materials Center.

Gopher and vole pressure may be affected by cover crop choice in orchards. Cover crops may provide a food source or shelter for pest rodents. The risk to the orchard is greater in the establishment years because rodents can kill or damage young trees. Legumes, particularly perennial clovers, are preferred by rodents. Monitor the crop closely and proactively control rodent populations before damage occurs to young trees. Providing nesting opportunities for rodent predators such as owls (owl boxes) or other raptors (perches) can be part of a holistic approach to reducing rodent pressure in orchards.

The selection of cover crops can be influenced by herbicide use history in the orchard. Herbicides are commonly applied in mature hazelnuts in the alleys or tree rows to maintain a weed-free ground surface for sweeping hazelnuts at harvest. These herbicides may or may not be compatible with a cover crop planted in the alleys. It is especially important to understand the tolerance of cover crops to pre-emergent herbicides. Some pre-emergent herbicides can have residual activity up to 2 years after application. Depending on what pre-emergent herbicide products were applied in the orchard, a producer may use the information below to select a cover crop. Table 2 outlines the effect of some commonly used pre-emergent herbicides on a select number of pollinator cover crops. Most cover crops, however, have not been tested for herbicide resistance. Use caution when planting cover crops after a history of pre-emergent herbicide use, and use herbicides that have a short residual before planting cover crops.

### Table 2. Cover crop compatibility depending on pre-emergent herbicide application timing.

| HERBICIDE | PLANTING CONCURRENT WITH APPLICATION | PLANTING 6 MONTHS AFTER APPLICATION |
|---|---|---|
| **Flumioxazin (Chateau)** | California poppy | California poppy, farewell to spring, sainfoin |
| **Indaziflam (Alion)** | No compatible species | Sainfoin |
| **Isoxaben (Trellis)** | Farewell to spring | Farewell to spring, hairy vetch |
| **Mesotrione (Motiff)** | No compatible species | No compatible species |
| **Napropamide (Devrinol)** | Phacelia, globe gilia, sweet alyssum, sainfoin | Farewell to spring, globe gilia, phacelia, sainfoin |
| **Pendimethalin (Prowl)** | California poppy | California poppy |
| **Rimsulfuron (Simazine)** | Hairy vetch, sainfoin | California poppy, farewell to spring, globe gilia, hairy vetch, phacelia, sainfoin, sweet alyssum |

## Planting a Pollinator Cover Crop

Cover crops are typically planted after harvest in the fall. Some years this can be difficult due to rainy weather. Planting occurs ideally in early October after preparing the soil for planting. Seedbed preparation typically involves disking, harrowing, and ring rolling. Many cover crop seeds are small and can be seeded with drop seeders or broadcast seeding. After surface seeding use a cultipacker, roller, or similar equipment to increase seed-to-soil contact. Larger seeds (e.g., legumes and grass) can be drill-seeded as well. When planted with forbs, creeping red fescue can be planted at 8 lb./acre. When a flowering cover crop is used in combination with red fescue, seed at approximately half the rate shown in Table 1. If more than one flowering species is added to a fescue mix then decrease the rate proportionally to the percentage cover desired for each species in the mix.

## Managing a Pollinator Cover Crop

Cover crops can be managed to reduce weeds and protect pollinators. High mowing (3–6 inches high) can help prevent weeds from setting seed, and increase diversity by letting more light penetrate the cover crop so species that otherwise may be out-competed can thrive. Mowing, however, can prevent some cover crops from blooming, thus affecting their attractiveness to pollinators. Partially mowing cover crops by leaving strips of unmowed cover crop or mowing alternate alleys will help maintain habitat for pollinators and beneficial insects while cover crops are still blooming. Delaying flail mowing before harvest until cover crops have set seed will maximize their ability to reseed for the following year.

Integrated pest management (IPM) monitoring can help minimize insecticide applications and their effects on pollinators and beneficial insects in cover crops. It is important to mow blooming cover crops prior to insecticide applications to minimize impacts to pollinator populations. Refer to the references below for more information on pesticide mitigation and bee safety.

## NRCS funding opportunities for cover crops in hazelnut orchards

The USDA NRCS provides technical and financial assistance to help producers and landowners make conservation improvements on their land that benefit natural resources. Two NRCS programs can provide financial assistance, EQIP (Environmental Quality Incentives Program) which provides cost-share assistance, and CSP (Conservation Stewardship Program) which provides further incentives for producers that have made conservation an important part of their operation. Erosion management and pollinator habitat are two priority resource concerns for the NRCS in Oregon. NRCS is currently providing opportunities for funding pollinator habitat in hazelnut orchards. Hazelnut growing regions of the Willamette Valley have targeted funding for the implementation of the cover cropping practice (340) in hazelnut orchards for erosion control. Although the primary resource concern being addressed with this funding is erosion control, these cover crops can be designed and managed with pollinator needs as a secondary resource concern. Ask your local NRCS field office about the Cover Crop practice (340) and the opportunity for additional technical and financial assistance.

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UCIPM Bee Precaution Pesticide Rating Website: ipm.ucanr.edu/bee-precaution-pesticide-ratings/

Mitigation Techniques to Protect Habitat: xerces.org/publications/fact-sheets/guidance-to-protect-habitat-from-pesticide-contamination

Organic Pesticides and Pollinators: xerces.org/publications/fact-sheets/common-organic-allowed-pesticides


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# Pollinator Plants for Pasture in the Willamette Valley

| Common Name | Species | Cultivars | Pollen Production[1] | Nectar Production[1] | Annual or Perennial | Soil Moisture | Specific Livestock Benefits | Palatability | Base Seeding Rate[2] | Seeding Rate into Mixtures[2] | Specific Livestock Concerns |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yarrow | *Achillea millefolium* | ___ | Very low | None | Perennial | Dry to moderately moist | Fair forage value | Low | 0.25-.5 lb/acre | | Volatile oils, alkaloids, and glycosides are considered toxic, but the plant is seldom overgrazed by foraging animals. |
| Swede | *Brassica napus* | Major Plus Swede | Medium | Medium | Biennial | Very well drained to moderately well drained | Low protein and high digestibility | High | 0.8-1.5 lb/acre | | |
| Kale or Collards | *Brassica oleracea* | Bayou Forage Kale, Impact Forage, Collards Siberian Style | High | Medium to High | Biennial | Very well drained to moderately well drained | High protein and digestibility | High | 3-4 lb/acre | 1-3 lb/acre | Should not constitute more than 75% of animals diet |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chicory | *Cichorium intybus* | Antler | Medium | Medium to High | Biennial / Perennial | Well drained to moderately well drained | Low to mod protein and high digestibility | Low | 3-5 lb/ acre | 2-3 lb/ acre | May reduce impacts of intestinal worms |
| Birdsfoot trefoil | *Lotus corniculatus* | Bruce Bull | Medium to High | Medium to Low | Perennial | Well drained to saturated | High protein and digestibility | High | 5-8 lb/ acre | | None |
| Bigleaf trefoil | *Lotus pedunculatus* | | Medium | Low | Perennial | Moist to saturated | High protein and digestibility | High | 3-5 lb/ acre | | None |
| Alfalfa | *Medicago sativa* | WS L550 | Medium | Very high | Perennial | Very well drained to well drained | High protein and digestibility | High | 10-15 lb/acre | | None |
| White sweet clover | *Melilotus alba* | Hubam | Low | None | Biennial / Perennial | Moderately well drained to well drained | Fair forage value | Fair to Good | 4 lb/ acre | 0.1-0.25 lb/acre | Some risk of bloat, mix with other frorage. Bitterness can reduce palatibility |
| Yellow sweet clover | *Melilotus officinalis* | | Medium | Medium | Annual / Biennial | Moderately well drained to well drained | Fair forage value | Moderate | 4 lb/ acre | 0.1-0.25 lb/acre | Some risk of bloat, mix with other frorage. Bitterness can reduce palatibility |
| Sainfoin | *Onobrychis viciifolia* | Shoshone | None | None | Perennial | Well drained | High protein and digestibility | High | 34 lb/ acre | 2-5 lb/ acre | Non-bloat |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phacelia | *Phacelia tanacetifolia* | Angelia | ___ | ___ | Annual | Well drained to poorly drained | High protein and digestibility | Moderate | 6-8 lb/acre | | Non-toxic, should be planted in mix |
| Plantain | *Plantago lanceolata* | Boston | High | None | Perennial | Moderarely well | Low to mod protein and high digestibility | High | 7-9 lb/acre | 1-2.5 lb/acre | Some animals selectively graze in mixed plantings |
| Berseem clover | *Trifolium alexandrinum* | Frosty | ___ | ___ | Annual | Well drained to poorly drained | High protein and digestibility | High | 8-12 lb/acre | 3-5 lb/acre | |
| Alsike clover | *Trifolium hybridum* | ___ | Very low | Low | Perennial | Well drained to poorly drained | Nutrition and protein decline with maturity | High | 3-5 lb/acre | 2-3 drilled | Bloat, photosensitivity and liver damage in horses |
| Crimson clover | *Trifolium incarnatum* | ___ | ___ | ___ | Annual | Moderately well drained to excessively drained | High protein and digestibility | High | 15-18 lb/acre | 10-12 lb/acre | Minimize bloat with grass mixtures |
| Balansa clover | *Trifolium michelianum* | Fixation, Paradana | ___ | ___ | Annual | Dry to poorly drained | High nutrition and crude protein | High | 5 lb/acre | 3 lb/acre | Doesn't tend to bloat |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Red clover | *Trifolium pratense* | Dyna-mite | Very low | High | Peren-nial | Dry to moist | High protein and digest-ibility | High | 8-12 lb/ acre | | Bloat, estrogen levels may cause conception problems in sheep |
| White clover | *Trifolium repens* | Stami-na, Haifa Domino, | Very low | Medi-um | Peren-nial | Well drained to poorly drained | High in protein and digest-ibility | High | 3-5 lb/ acre | | High bloat potential when grown alone |
| Arrow-leaf clover | *Trifolium vesiculo-sum* | ___ | ___ | ___ | Annual | Well drained to mod-erately well drained | High protein and digest-ibility | High | 5-10 lb/ acre | | Minimal bloat |

[1] *Pollen and nectar rating are based on relative abundance over the entire bloom period of the species.*

[2] *Seeding rates are expressed as drilled rates, broadcast rates can be up to twice the amount of drilled rates.*

## Acknowledgments

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