Establishing pollinator habitat in California orchards

Planting pollinator habitat on farms is a growing practice as producers increasingly recognize the importance of diverse flowering resources to sustain both wild and managed bees. This guide provides recommendations to improve the performance of pollinator habitat through strategic planning, site selection, site preparation, plant selection, and establishment and maintenance techniques that have been trialed in California's Central Valley.

Benefits

Studies have demonstrated the benefits of pollinator plantings for agricultural In California. Wildflower habitat attracted on average six times the number of native bees and three times the diversity compared to unplanted controls, without attracting pests. These benefits to bees can extend to adjacent crops. Increased yield has been shown in Michigan highbush blueberries, California watermelons and almonds when wildflowers are planted on field borders.

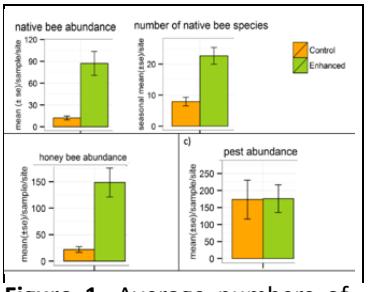


Figure 1. Average numbers of (a) native bees, (b) native bee species, (c) honey bees, and (d) pests from 18 enhancements and control sites in agricultural landscapes from the central valley 2011-2013.

Challenges

Establishment of the mixed species plantings that support bee diversity through successive bloom over the season presents a unique set of challenges. Weeds are more difficult to identify and target when there are multiple desirable species to avoid. The germination requirements and timing of native wildflowers are not well known to most farmers. Dominant species within the mix may overtake other species that fill gaps in the sequence of bloom. These challenges can be minimized with site selection and preparation methods that limit weed establishment, careful selection of plant species, and seeding rates that adjust species according to germination timing and competitive ability.

Plant Selection

Species that are native to California are likely to establish best because they are adapted to local soil and climate conditions. They may also provide the most benefit to wild bees that evolved with them. Drought tolerant species can thrive without irrigation, lowering costs and outcompeting most weeds which require more moisture. Wildflowers vary in their support of bees, so choosing plants that bees prefer can increase the cost-effectiveness of the plantings.

Flowering hedgerows composed of woody perennials support pollinators and are perhaps more straightforward to install and maintain because their management is more similar to that of an orchard. However, wildflowers provide more floral resources and support more native bees for a given acreage, (Figure 2), making them worth the investment to establish and maintain even after shrubs have matured to flowering.

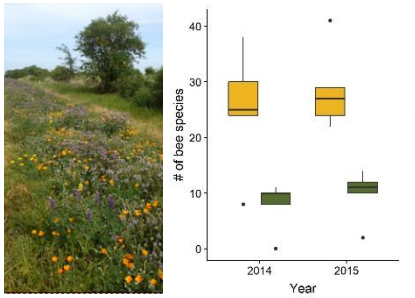


Figure 2. Diversity of bees collected at hedgerows with wildflower strips (yellow) versus hedgerows without wildflowers (green).

Site Selection

Plant wildflowers on the border of almond orchards to allow for perennial plants that would interfere with orchard management in the understory. Choose a site with low weed pressure, and watch for "deal-breaker" weeds that can severely compromise success (Table 2). Avoid areas with heavy soil compaction, which can prevent root growth and establishment. Choose sunny locations favored by bees. Irrigation is not required for installation and maintenance in central California, but areas with potential for irrigation have two advantages. The timing of germination can be controlled to manipulate bloom to support bees before almond flowers. Irrigation also can be used during site preparation to install solarization or to flush weed germination for chemical control.

Site Preparation

Effective weed control is essential to a successful planting. Common agricultural weeds are early-germinating, fast-establishing, prolific seed producers that quickly choke out native vegetation if left unchecked. It is most cost-effective to control weeds before sowing wildflower seeds because this avoids the expense and trouble of selective weeding. We recommend two approaches for pre-planting weed control in California: solarization and chemical weed control. Each has pros and cons depending on the resources available, including space, time, irrigation, site conditions, farm management practices, cash flow and labor timing (Table 1).

Solarization is the most effective approach. This method involves a single irrigation at peak summer day length followed by immediate covering of soil with clear plastic sheeting. The resulting greenhouse effect kills weeds and weed seeds in the top 6 inches of soil, minimizing weed growth until after wildflower stands have successfully established.

Solarization is expensive up-front due to the costs of irrigation infrastructure, UV-resistant plastic and labor crews to install and remove the plastic, but it substantially reduces weed control costs after planting. In addition, solarization can be completed in a few months, so wildflower seed can be sown in the same year site preparation is initiated (Figure 3).

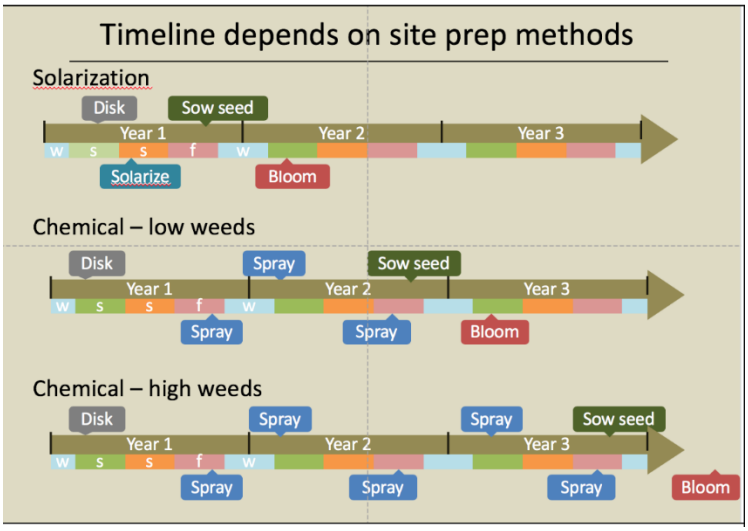


Figure 3. Timeline from initiation of site preparation to first bloom depends on weed control methods and weed pressure.

Chemical weed control avoids some up-front expenses and labor costs of solarization, but requires more advance planning and higher investment in weed control after wildflowers are planted. This strategy cannot kill weed seeds in the soil, so it requires multiple cycles of sprays following rain or irrigation to kill weeds that germinate at different times of year. After disking the seed bed to clear existing vegetation, spray germinating weeds with glyphosate, a nonselective herbicide,

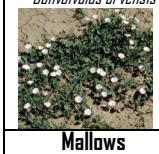
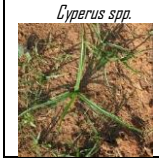
Table 1. Pros and cons of soil solarization and chemical treatment for weed species prior to planting wildflower mixtures

Solarization		Chemical control	
Pros	Cons	Pros	Cons
• Better overall weed control leading to better wildflower establishment • Lower maintenance costs after planting • Shorter site prep. timeline • Compatible with organic farm management • Reduced chemical use	• Higher upfront costs of materials and labor • Requires irrigation at time of plastic installation • Plastic waste	• Lower upfront cost • Doesn't require irrigation infrastructure	• Less effective weed control leading to mixed stands of weeds and wildflowers • Higher weed control costs after planting • Requires ideally 2-3 years of site preparation • Not compatible with organic practices

before they set seed. Spray again in spring to control winter-germinating weeds, and again in the fall just prior to sowing wildflower seed. Irrigation can be used to germinate weeds in case of drought. For sites with high weed pressure, an additional year of treatment is necessary to deplete the weed seed bank. In most cases, weed seeds remain in the soil so weed infestations must be stringently controlled during the first year of wildflower establishment.

Regardless of the weed control method used, **eliminate all ground disturbance after initiating weed treatments**. Each disturbance brings new weed seeds to the surface, undoing previous investment and actions.

Table 2. Deal breaker weeds

	Description	How to control
Field bindweed *Convolvulus arvensis* 	Hardy perennial with extensive rhizome system that allows plant to regrow from root fragments as short as 2 in. long. Drought tolerant	Tillage of young seedlings can be effective, but after 3-4 weeks cultivation is ineffective. Till every 2-3 weeks for best results. Repeated herbicide application can suppress but won't generally eliminate. Solarization will not control because of rhizomes
Mallows *Malva spp.* 	Annual/biennial, 2-5 ft tall with lily-pad-shaped leaves and deep taproot. Germinates in fall and produces seed within as little as 15 days.	Very difficult to remove after seedling stage because of taproot. Glyphosate alone often ineffective when plants are large; tank mixes with shark (carfentrazone-ethyl) perform better.
Hairy vetch *Vicia villosa.* 	Although these species provide floral resources for bees, they are highly competitive and can suppress germination and establishment of sown native wildflowers	Glyphosate doesn't reliably control it. Best control is achieved when mixed with Shark and sprayed in the spring when the plants are small. Solarization does not kill the hard seed of hairy vetch.
Fluvellin *Kickxia elatine* 	Branched, mat-forming annual that thrives in hot, dry conditions and germinates all year long. Leaves are covered with soft hairs and are heart/arrow-shaped	Difficult to control when mature. Spray with glyphosate at the seedling stage Solarization is effective.
Prostrate knotweed *Polygonum spp.* 	Annual or short-lived perennial with small leaves and wiry stems forming a prostrate mat. Establishes in compacted soils and may resprout from buds at the crown.	Prevent soil compaction. Best controlled with glyphosate in the early seedling stage before the plant becomes hardened off. Solarization is effective.
Nutsedge *Cyperus spp.* 	Perennial sedge plants that thrive in moist poorly-drained soils. Produce underground tubers and rhizomes from which new plants sprout.	Tilling mature plants will worsen infestations: till small plants every 2-3 weeks to limit tuber formation. Solarization can be effective. Most herbicides are not effective against tubers; repeated glyphosate applications will suppress but not eliminate nutsedge.

Solarization tips

1. Solarization is most effective during the longest days of the year because solar radiation raises soil temperatures. Aim to install plastic by the summer solstice if possible, and no later than mid-July. Do not attempt solarization in shaded areas.

2. Solarization is not recommended for sites with substantial infestation of hard-seeded or strongly rhizomatous weed species. Species like hairy vetch or burr clover are not affected because their seeds require mechanical or cold treatment to break dormancy. Species with deep taproots or rhizomes like mallows and bindweed (Table 2) can re-sprout from depths below the 6 inches that are heated under the plastic.

3. Order clear, UV-resistant plastic well in advance of the target installation date. Highest soil temperatures and better weed seed kill are achieved with 2-mil plastic but it must be custom-ordered further in advance, and is more prone to tears. We

have had good success with 4 mil plastic, which is more readily available and sturdier.

4. Disk the site to prepare a fine seed bed with an even surface. Large irregularities in the soil surface create air pockets under the plastic, preventing the soil from reaching targeted high temperatures.

5. After disking, irrigate the site 1-3 days prior to laying plastic. Micro-sprinklers can be a short-term solution if other irrigation is not available. Lay plastic when the top 6 inches are moist but the surface is dry enough to work in.

6. Roll out the plastic and bury about 6 inches of the edge in the trenches you prepared. The most cost-effective method is to secure one short end by hand, then use a tractor with a scrape blade at a slant to dig a ditch along one of the long edges. Stretch out the plastic and place it in the ditch, then drive back over with the scrape blade to cover the ditch and the plastic edge. You may need to secure some areas by hand. Once one side is secure dig another ditch with the scraper, stretch the plastic into and tack it down in a few spots and make a final pass with the tractor to push the rest of the dirt into the ditch and over the plastic. Secure the final short edge by hand. Pull the plastic as taught as possible at this stage to avoid wrinkles or looseness, which can lead to tears or air pockets that reduce soil temps.

7. To lay two pieces of plastic side by side, unroll them together to bury their shared edges in a single trench. Soil used to bury plastic edges will contain untreated weed seeds so minimize this area in the wildflower planting by sharing the edges of two plastic pieces.

8. Animals walking across the plastic can tear holes which allow heat to escape, inactivating solarization. Either fence the site to keep animals away or check the plastic at least once/week and repair holes with UV-resistant tape.

9. Leave the plastic on site a minimum of 8 weeks, and ideally until just prior to sowing wildflower seed. This prevents weed seed rain from contaminating the treated seed bed. Before removing plastic, cut or pull and remove weed material which may contain seeds from a three foot border surrounding the plot, or further if the weeds nearby are tall and could drop seed on the bed. When removing plastic, ensure the untreated soil used to bury the edges is left in place, as scattering this soil would contaminate treated areas with weed seeds. Install wattles on sloped sites to prevent untreated soil from eroding downslope and contaminating the treated area. Do not disk or disturb beds as this will bring untreated weed seeds to the surface. Solarization plastic can be reused if it is intact.

Chemical site prep tips

1. The effectiveness of pre-planting chemical weed control depends on the proportion of weed seeds that are flushed from the seed bank. Weed species germinate at different times of year, so even minimal chemical control requires a full year to flush fall, winter, spring and summer-germinating weeds. Two to three years will provide more effective control. Use irrigation if there is no rainfall to stimulate germination.

2. Disk site prior to spray treatments only if compaction is an issue. Once herbicide sprays are initiated, halt further ground disturbance. Disking is a commonly-used method of controlling weeds on Central California farms, but it can spread rhizomatous weeds and bring new weed seeds to the surface.

3. Spray germinating weeds with a broad spectrum herbicide before they flower so there is no chance of seed set. If rhizomatous weeds like field bindweed are not avoidable, spray in fall when the plants are drawing resources belowground. This will translocate the herbicide to deep rhizomes and more effectively kill the plant.

4. Watch the plot and broadcast spray every flush of weeds before they flower. If the weed infestation is heavy, or if “dealbreaker weeds”, like field bindweed, hairy vetch, or mallows are abundant, repeat treatments for up to three years before sowing seed.

Sowing seed

Sow wildflower seed in the fall so early germinating species can pre-empt weeds and later species receive the cold treatment or day-length cues that stimulate germination. If possible, time sowing just prior to a rainfall event, as the moisture will prevent the seed from blowing away and stimulate germination of the early species. Early flowering resources are important to support bee populations prior to almond bloom in February, so for almond we recommend planting by mid-October, followed by irrigation to initiate germination. If fall rains continue after sowing seed, no further irrigation is needed, otherwise continue irrigation to prevent tiny seedlings from desiccating. Irrigation timing and amounts will vary with temperatures and soil type. Normally only a couple of rounds in the first few weeks will allow young roots to reach a safe depth but in very dry years additional irrigation will be needed. If neither irrigation nor rainfall are available, sow seed when convenient in the fall so the seed is ready to respond when rain comes.

Wildflowers can be sown using various types of equipment, including drop-seeders, broadcast-seeders, belly-grinder style spreaders, hand-scattering, or drill seeders. If using a drill, set the drill to place seed no deeper than 0.25-0.5 inch or disable hydraulics to avoid placing seed too deep. Most wildflower seeds are very small and germinate best with a minimal covering of soil so light can penetrate. Bulking agents increase the volume of the seed mix to ensure even spread over a large area. Polenta is very effective because it has similar density to seeds, so seeds stay evenly suspended. Other options include rice hulls, wheat hulls, sand and sawdust.

Immediately prior to sowing seed, scratch the soil surface lightly using a light chain harrow or other implement that disturbs only the top ½ to 1 inch. Turn the harrow upside down if the soil is soft and more than an inch is disturbed. The goal is to minimize soil disturbance to avoid re-surfacing weed seeds but to generate a crumbly layer that the seeds can intermix with. Even spreading of the seed mix is critical because bare ground is vulnerable to weed invasion so calibrate equipment carefully before seeding each plot.

Use a ring-roller, culti-packer or walking to press the seed into the soil immediately after sowing. Seed-soil contact is required for germination and to prevent seed from blowing away. Never cover the seed bed with mulch or additional soil after sowing.

If herbivory from rabbits, rodents or birds is possible, cover the planting with lightweight row crop cover (Agribon AG19 or similar) immediately after sowing seed to protect germinating seedlings. Remove the cover when seedlings have established and before they become stunted or distorted by the covering.

Site maintenance – establishment phase

The establishment phase is the most critical maintenance period to ensure a successful planting in the long term, so plan on spending more effort during the first year.

Check the site every two weeks in the spring for new germinating weeds and spot spray with a backpack sprayer before they grow large or dense enough to choke out native plant seedlings. Broadcast sprays of grass-specific herbicide can control weedy grasses if it is applied when grasses are young, ideally no more than 2-3 inches tall. It is better to err on the side of harming a few natives in order to kill the weeds, especially in the early stages of wildflower establishment. If spot spraying is not possible or if weeds are too mature to prevent seed drop (late flowering or later), control weeds with mowing, string trimming, hand weeding or hoeing and remove seed heads. Flame weeding can be used in organic settings but must be employed at the seedling stage to be effective.

Long term maintenance

If weed control was effective and consistent during the year of establishment, subsequent years should require substantially less effort. Periodic checks and limited spot spraying or hand weeding may be all that is required. Once wildflowers have established, limit or remove irrigation because natives are more drought-tolerant than most common weeds. Irrigation after the establishment phase favors weeds, and drought can be used as a form of weed control. Mowing or burning at the end of the season may help open up space for germination of new wild flowers but plots can rebloom even without this step.

Refreshing the species diversity with seed addition in years after initial establishment may be necessary. This seems to be especially important for *Phacelia ciliata*, a key species if the goal of the wildflower planting is to provide bloom for bees before almond flowers.

Recommended seed mix

This mix contains bee-preferred wildflowers for all seasons with seeding rates tailored to promote coexistence.

Species	season	Recommended rate*
Nemophila menziesii	early	7
Phacelia ciliata	early	7
Eschscholzia californica	early, mid, late	3.5
Collinsia heterophylla	early, mid	7
Phacelia californica	early, mid, late	3
Clarkia unguiculata	mid	6.5
Clarkia williamsonii	mid, late	6.5
Helianthus bolanderi	mid, late	3
Trichostema lanceolatum	mid, late	10
Grindelia camporum	mid, late	2.5

* Live seeds /ft^2. Mixes may vary by region. For more detail, see resources below.

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Resources

- www.icpbees.org
- https://williamslab.ucdavis.edu/outreach/
- https://xerces.org/pollinator-conservation/agriculture/pollinator-habitat-installation-guides/

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