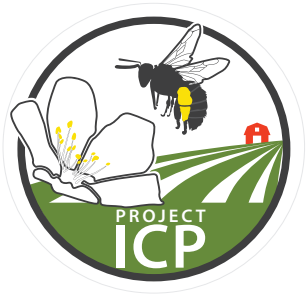
Establishing Wildflower Habitat to Support Pollinators of California Row Crops

PROJECT ICP

UC DAVIS
UNIVERSITY OF CALIFORNIA

XERCES SOCIETY
for Invertebrate Conservation



Integrated Crop Pollination (ICP) is the combined use of multiple pollinator species, habitat enhancements like wildflower plantings, and crop management practices that support bees, to provide reliable and economical pollination of crops. These pollination strategies are the focus of the Integrated Crop Pollination Project – a multi-year Coordinated Agricultural Project funded by the USDA-NIFA Specialty Crop Research Initiative. Members of the project team are investigating the performance, economics, and farmer perceptions of different pollination strategies in various fruit, nut, and vegetable crops.

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ESTABLISHING WILDFLOWER HABITAT TO SUPPORT POLLINATORS OF CALIFORNIA ROW CROPS

Guidelines for Establishing Pollinator Habitat on California Farms

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A stand of serpentine sunflower (*Helianthus bolanderi*) in central California. *Photograph: Williams Lab, UC Davis.*

Acknowledgments

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Editing and layout: Emily May, The Xerces Society for Invertebrate Conservation.

Cover Photograph

Front: A yellow-faced bumble bee (*Bombus vosnesenskii*) visiting *Lupinus microcarpus var. densiflorus* flowers in a California wildflower planting. *Photograph: Williams Lab, UC Davis*.

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TIMELINE FOR ESTABLISHING WILDFLOWERS

Year 1*

CHOOSE A SITE

Select a sunny site with manageable weeds that is protected from pesticide drift.

pg. 4

ERADICATE WEEDS

Prepare the site for seeding by killing existing weeds. This step takes time and is essential for success.

pg. 5

SELECT PLANT MIX

Choose a plant mix suitable for the site conditions and your goals for the planting.

pg. 8

SEED THE SITE

There are many different ways to efficiently and effectively seed a planting.

pg. 10

Year 2

MANAGE WEEDS

Mow or spot spray to control remaining weeds and create space for wildflowers to grow.

pg. 12

Year 3+

MAINTAIN OVER THE LONG TERM

Continue to monitor and manage problem weeds as needed.

pg. 12

* Site preparation can take longer than one year depending on the weed community and preparation method.

PLANTING WILDFLOWERS TO SUPPORT POLLINATORS OF CALIFORNIA ROW CROPS

INTRODUCTION

A striped sweat bee (*Halictus* sp.) visits watermelon flowers to collect pollen. *Photograph: Williams Lab, UC Davis.*

California's Central Valley is home to such an abundance and variety of row crops it has been called the breadbasket of the nation. Many of these crops, like vine seed, sunflower, squash, and melon, require insect pollination in order to produce large, high-yielding fruit. Most California row crop growers rely primarily on managed honey bees (*Apis mellifera*) for pollination, as they can be rented from commercial beekeepers to provide on-demand crop pollination. In addition to these managed bees, wild bees can provide free pollination service when their habitat requirements are met. There are hundreds of species of wild bees in the state of California, and dozens that visit row crops like watermelon, squash, and sunflower. Wild bee pollinators of Central Valley row crops include several species of longhorn bees, sunflower bees, bumble bees, digger bees, squash bees, and sweat bees.

Row crops benefit from having a diverse set of pollinator species for several reasons. Bee diversity increases stability of crop pollination because if one bee species is uncommon in a particular year or region, other species may be available to fill the gap. In addition, some wild bees, particularly large-bodied bees like bumble bees, often deposit more pollen in a single visit than honey bees. Furthermore, wild bees and honey bees often approach and interact with flowers in different ways, with the result that when bee types are combined they provide more complete pollination and higher yield. For example, honey bees tend to land in the center of strawberry flowers and pollinate the top, whereas small sweat bees tend to land on petals and circle the base of the flower, pollinating the edges. The result is a more reliably pollinated and symmetric fruit. Unlike honey bees, some wild bees are able to "buzz pollinate" flowers. Once they land on a flower, these bees vibrate their wing muscles at a high frequency to release large amounts of the pollen. This ability is particularly important for crops like tomato, where the pollen is contained inside of the anthers and not easily accessible like the pollen on many other crop flowers. Buzz-pollinating bees are highly efficient tomato pollinators, buzzing pollen from flowers like salt from a salt shaker; honey bees rarely visit tomato flowers. Increasing the abundance and diversity of bees pollinating row crop fields can help to provide consistent pollination throughout bloom.

Wild bees are not directly managed in the same way that honey bees are, because they live freely in and around farms rather than in hives. However, their populations can be indirectly managed by maintaining natural areas that provide these bees with food and shelter. Researchers at UC Berkeley and UC Davis found that wild bees can meet 100% of the pollination needs of California watermelon fields in landscapes where 30% of the surroundings within 1.2 miles of the crop field is natural habitat. Researchers at UC Davis are now asking whether planting wildflowers on farms without surrounding habitat can increase bee diversity and crop pollination even when honey bees are present. They found an eight-fold increase in bee abundance and nearly four-fold increase in bee species richness on field

borders planted with wildflowers compared to control borders without wildflowers. Watermelon fields with the wildflower border yielded increased fruit mass near to wildflower plantings and increased density of fruit that continued at least 80 meters into the field (the farthest distance measured). These plantings also provide pollen and nectar resources for honey bees present on the farm after crop bloom, making them a win-win strategy for both managed and wild pollinators.

Wildflower plantings have other economic, ecological, and aesthetic benefits besides providing resources for pollinators. These natural areas provide food and shelter for other beneficial insects, such as predatory beetles and parasitic wasps that provide valuable pest control services. Plantings can also help stabilize soil and reduce erosion, and can improve local surface water quality through better infiltration and reduced runoff. Plant mixes can be tailored to meet the needs and goals of the individual farm and planting site.

This guide provides the steps to establishing a native wildflower planting to support pollinators of California Central Valley row crops. There are many other ways to support these pollinators, including maintaining existing natural areas, minimizing bee exposure to toxic pesticides, and installing hedgerows with flowering trees and shrubs such as redbud, manzanita and California lilac. The plant mix suggested in this guide (*Appendix 3: Recommended Plant List*) is designed to support a diverse community of wild pollinators and supplement honey bee service for improved pollination. If other goals are identified (e.g. to support rare pollinators) then additional strategies may be needed. For more information on ways to support pollinators on California farms, see our list of resources at the end of this guide.

HOW DO WILDFLOWER PLANTINGS SUPPORT POLLINATORS?

Food

Female bees collect pollen and nectar from flowers to feed their offspring and to maintain their own energy levels when flying around. Although some bees are specialists, meaning they only collect the pollen from a specific type or group of flowers, most bees are generalists that collect pollen from many different types of flowers. Many generalist wild bees and a few specialist bees visit California row crops for pollen and/or nectar. These wild bees need abundant, diverse flower communities close to their nests to provide food for their offspring. More abundant food locally means more offspring and more robust populations of wild crop pollinating bees.

Shelter

About 70% of wild bees nest in the soil, including most of the bees that pollinate row crops in California. Soil-nesting bees tend to prefer nesting in undisturbed, well-drained areas with some bare soil surfaces. Wildflower plantings can provide ideal undisturbed nesting areas for bees that are close to the pollen and nectar resources they collect through the summer. Research on California Central Valley row crop farms found that more bees nest in the ground in wildflower plantings than other field borders around the farm. Certain wildflowers also provide nesting materials for stem-nesting bees, which build nests in hollow or pithy plant stems.

Protection from pesticides

Many insecticides used to control pests in fruit and vegetable crops are toxic to bees. Wildflower strips can act as a refuge from pest management activity when sited and managed correctly to protect bees living and foraging in those areas from pesticide exposure. Use drift mitigation methods to prevent harmful pesticides from drifting or leaching into wildflower plantings and other nearby flowering habitat. Consider planting vegetative drift barriers between pollinator habitat and treated crop fields.

SITE SELECTION

WHAT TO CONSIDER WHEN CHOOSING A SITE

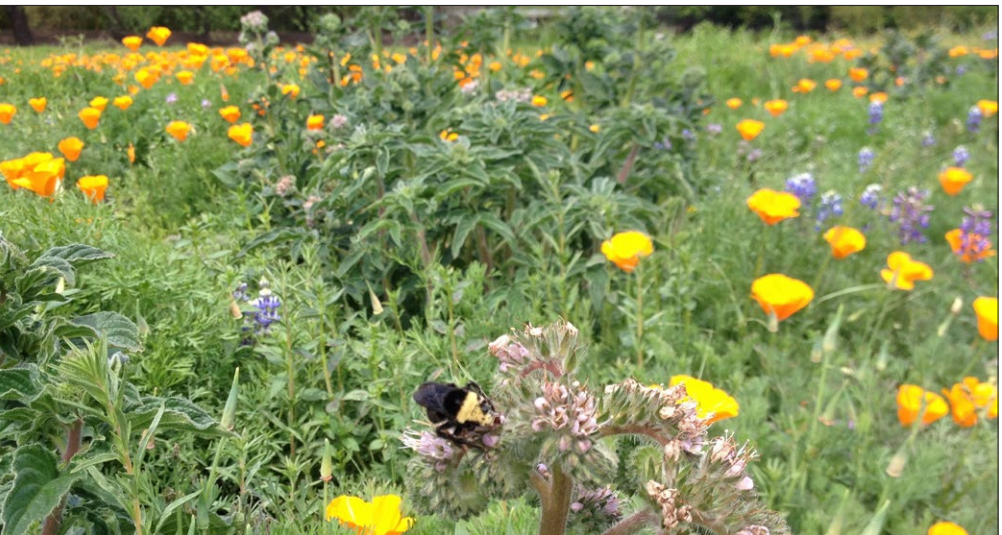
Selecting an appropriate site for establishing flowering pollinator habitat is critical for long-term success. Factors to consider when selecting a site to plant are listed below. When space is limited and the planting location is sub-optimal, extra site preparation and management may be needed to ensure a successful planting.

- **Evaluate existing weed pressure and identify problem weeds**. Some species of native wildflowers compete poorly against weeds during the first year of growth, so pre- and post-planting weed management is an important step for reducing weed competition and allowing native wildflowers to germinate and establish. However, there are certain weeds that are very difficult to manage, which will undermine the success of a planting. A site dominated by one or more of these problem weeds will require very thorough pre-seeding weed eradication; consider alternative sites if available *(see Appendix 2: Common Problem Weeds)*.

- **Look for sunny, well-drained areas.** Most native wildflower species require partial to full sun exposure during the day. The ideal areas for establishing habitat have well-drained soils with full sun exposure for at least half the day. If using solarization for site preparation, the area should have full sun exposure the entire day. Steep areas that are prone to erosion can benefit from establishment of wildflowers like phacelia, woolly sunflower, lupines, poppy, or lotus, but consider using wattles for erosion control or lightly irrigating to initiate germination before fall rains cause mass erosion.

- **Minimize possible pesticide drift onto planting.** Choosing a site with a buffer, like a farm road, between treated crop fields and the planting can help to reduce pesticide exposure within the flowering area. In many California landscapes the only areas available for planting habitat are field borders close to treated crops, so further work is needed to understand potential pesticide exposure to bees on such close plantings. Be aware that aerial applications create the most drift, and airblast sprayers result in significantly greater drift than other ground applications. Using reduced-risk equipment such as tower sprayers, hooded sprayers, or electrostatic sprayers can greatly reduce drift. If space is available between the planting and your crop, consider planting a non-flowering vegetative barrier, such as a coniferous windbreak, to minimize pesticide drift onto flowering plants.

Choose a site for wildflower habitat that will protect bees living and foraging there, like this *Bombus vosnesenskii,* from exposure to bee-toxic pesticides. *Photograph: Kimiora Ward, UC Davis.*



- **Optimal size/shape of planting: bigger is better.** The larger the planting, the greater the benefits for pollinators. Ideally, the planting should be at least a half-acre in size and shaped more like a rectangle than a thin strip to minimize the amount of habitat edge where weeds tend to invade.

SITE PREPARATION

THE KEY TO A SUCCESSFUL PLANTING

Effective weed management before seeding is essential for achieving good wildflower germination and establishment. It helps ensure long-term planting success and will reduce costly and labor intensive weed management after wildflowers are sown. If weeds are not managed before seeding, wildflowers will have to compete with weeds for space, water and light, and the planting will never reach its full potential. Controlling weeds before planting desirable species is much more cost-effective, because you can treat all weeds in one action without having to protect sown species.

There are many different options for weed control. The method you choose will depend on how flexible your planting date is, the amount of time and money you can devote, the types of weeds on your site, and your tolerance for weedy species in the resulting habitat. Even if you can tolerate some weeds in your wildflower strip, thorough weed control prior to planting is essential to allow wildflower seedlings the space, light and water they need for initial germination and establishment.

At least one full season of weed control is needed for the common weeds that can undermine planting success. Do not rush weed management before seeding. Different weeds emerge and grow – and therefore must be controlled – at different times throughout the year. Depending on the weed growth habit (e.g. annual, biennial, or perennial seeds and rhizomes) and level of pre-existing weed pressure, particular management strategies may be necessary. Consult the University of California – Cooperative Extension Weed Research and Information Center website at wric.ucdavis.edu for more information on controlling difficult weed species.

Herbicides are the most common weed control tool used to prepare a site for wildflower establishment. *Photograph: Miles Daprato, Solano Regional Conservation District.*

SITE PREPARATION METHODS

Herbicides

Herbicides are the most common weed control tool used to prepare a site for wildflower establishment. One full year of carefully timed herbicide treatments is required for sites with low weed pressure, while sites with moderate to heavy weed pressure will need two or more years of herbicide treatment for adequate site prep. Some common weeds have developed resistance to herbicides, so if these weeds are present on your site you should consider solarization as your method of weed control. For effective weed control, first mow and rake off existing vegetation in the fall. Once new weed seedlings reach ankle height after the first fall rains, apply a nonpersistent postemergent herbicide such as glyphosate per label instructions. As with any herbicide or other agricultural practice, runoff to waterways

Burying the edges of solarization plastic using a bar-mounted trenching implement. *Photograph: Jessa Kay Cruz, The Xerces Society.*

Solarization is a highly effective non-chemical method for preparing areas for wildflower establishment. *Photograph: Andrea Drager, UC Davis.*

should be minimized or avoided whenever possible. Fall-and spring-germinating weeds pose the greatest competition threat to newly germinating wildflower seedlings, so starting management at the beginning of weed growth in the fall is critical because it allows at least two flushes and burndowns of the fall-germinating weeds. Watch for early spring green-up and apply herbicide again when spring weeds are ankle height. This early spring treatment is key to controlling cool season grasses that are dormant in mid-summer and will not be killed off by glyphosate at that time. Apply herbicide again every six weeks through the growing season, or whenever a new flush of weeds reaches ankle height. Consider irrigating to flush additional crops of weeds during the dry summer months. Be sure to treat weeds before they bolt and flower, to avoid adding weed seed to the seed bank. The goal is to eliminate existing and newly germinating weeds, while preventing seed set that will result in a new flush of weeds when your wildflowers are present. Avoid preemergent herbicides, as these will limit the germination of wildflowers in your seed mix. Do not plant wildflowers in fields treated with atrazine or similarly persistent herbicides in the past two years.

Solarization

Solarization is a very effective, non-chemical method for controlling weeds that can be started later than herbicide treatment, as late as the June before fall sowing. This technique is labor-intensive and expensive up front, but the weed control is so effective you will have less work to control weeds in the early establishment phase, so it may save you money in the long run. The method uses a combination of soil moisture and a layer of UV stabilized plastic (such as high tunnel greenhouse plastic) to capture and trap solar radiation, generating temperatures high enough to cook all vegetation as well as most weed seeds in the top six inches of soil. Moisture captures the solar radiation as heat and the plastic traps the heat in the same way a car does in the summer sun, generating temperatures as high as 140° F which is necessary for killing dormant weed seeds.

For effective solarization, choose a site without shade that is level or south to west facing, to ensure it is exposed to sun. Clear existing vegetation off the site in spring by mowing and raking. Disk to prepare a level, fine seed bed. Irrigate 1-2 days before laying down the plastic to ensure moisture is available to capture the sun's heat. The plastic should be in place by the summer solstice so the long days maximize sun exposure. Bury the edges to prevent airflow and heat loss from underneath the plastic. Check the plastic for rips and tears throughout the growing season, especially in areas where deer are abundant. Repair any rips using greenhouse plastic repair tape to prevent the heat from escaping. You can remove the plastic any time after the 4-6 weeks of high temperature required to kill dormant weed seeds, but it is best to leave the plastic on until you sow wildflower seed in the fall, to prevent weed seed rain from

contaminating your plot. Before removing plastic be sure to remove any dead or living plants along the border that could drop seed into your treated plot. Take care not to spread untreated dirt used to bury the edges of the plastic over your treated plot. Solarization is not recommended for areas with bindweed, nutsedge, quackgrass or other rhizomatous grasses, or hard-seeded weed species like hairy vetch or black medic. See *http://bit.do/solarizationvideo* for a video explaining the steps of the solarization process.

Other organic methods

Other organic techniques such as smother crops, sheet mulching and use of organic herbicides have been trialed in California. For more information see the guide *Organic Site Preparation for Wildflower Establishment* (The Xerces Society for Invertebrate Conservation).

Do not till the soil after using any of the above weed control strategies. Tillage will bring dormant weed seeds in the soil up to the surface, where they will germinate and compete with wildflower seeds for soil, water, and light.

Repeated tillage

Repeated tillage is not recommended on most Central Valley farms because of the prevalence of bindweed. The underground shoots of this weed can regenerate new plants from fragments as small as one inch in length, so tilling spreads the weed around your farm instead of killing it. Repeated scraping of vegetation with a box scraper may be a viable alternative.

Each of these preparation techniques has pros and cons. For example, although solarization is extremely effective, can be started as late as the spring before planting, and can be used in an organic-certified or other chemical free settings, it is also labor-intensive, has high up-front costs and creates plastic waste. Consider your ability to manage weeds before and after planting, and preferred installation method and timing when selecting your site preparation method. Consult with experts at local native plant nurseries or seed vendors, conservation districts, or NRCS to determine the best strategy for your farm.

Thorough site preparation is essential for getting good wildflower germination and establishment. At least one full year of weed control is needed before seeding. *Photograph: Kimiora Ward, UC Davis.*

PLANT SELECTION

WHAT TO CONSIDER WHEN CHOOSING A SEED MIX

Wildflower mixes can be designed to meet many different goals and site needs. It can be helpful to consult with plant experts when designing a site-specific mix (*see Appendix 1: Additional Resources*). Some of the main considerations for creating a mix for crop pollinator habitat are below.

- **Provide season-long bloom to supply diverse pollen and nectar sources throughout the growing season.** Diversity in the pollinator community can increase stability of crop pollination because if one bee species is uncommon in a given year, others may be available to take its place. Although many bee species have short life cycles their flight periods vary, with some species active in early spring, others in late spring, and others in summer through early fall. Many other bee species, including bumble bees and sweat bees, have long life cycles or multiple generations in a single year, staying active from early spring through early fall. To support diversity of short-lived pollinators as well as long-lived bumble bees and sweat bees, you need diverse and abundant flowering plant resources throughout the growing season to support production of offspring that will be present during crop bloom the next year. To ensure that they never experience a gap in food during the season, plant a seed mix that will provide flowers – and preferably more than one species –from spring through fall.

- **Choose plants based on site conditions.** Plants have variable requirements for soil type and moisture, so tailor your seed mix to include plants that are well-adapted for the soil, moisture, and sun exposure conditions of the site. Native wildflowers are typically the best suited to local environmental conditions and are often preferred sources of nectar and pollen for wild native pollinators. Look for local seed sources that can supply local "ecotypes" of native wildflowers adapted to local soils and climate. These may also be better synchronized to bloom when their pollinators are active.

- **Choose a diverse mix of plants preferred by major crop pollinators.** See *Appendix 3: Recommended Plant List* (pages 16-17). These plants have been evaluated by UC Davis researchers for their attractiveness to pollinators and their ability to establish successfully on Central Valley farms.

A long-horned bee (*Melissodes* sp.) foraging on California phacelia (*Phacelia californica*). *Photograph: Kimiora Ward, UC Davis.*

Diverse flowering mixes that bloom through the season help support diverse and abundant pollinator populations. *Photograph: Kimiora Ward, UC Davis.*

- **Use optimal seeding rate.** The optimal seeding rate depends on the diversity and species composition of your wildflower mix because of differences in seed size and competitive ability of wildflower species. Use the recommended rate for mixes designed for pollinator plantings; in general, these mixes range from 25-45 live seeds/square foot, which translates to about 6-12 lbs/acre. If the site has been properly prepared and seed is sown at the right time of year, lower seeding rates yield higher diversity of wildflowers because late-germinating species have less competition from early starters. If you would like to develop your own mix, consult a local plant expert or your seed vendor or use the Xerces Society seed rate calculator to help determine the best seeding rate for each species (see *Appendix 1: Additional Resources*).

- **Include a mix of annuals and perennials to span the full growing season.** UC Davis researchers have found that a mix of annuals and perennials can provide season-long bloom from February through September.

- **Grasses should comprise no more than 25% of the mix.** Inclusion of native bunch grasses such as blue wild rye and purple needlegrass is being trialed in Central California pollinator plantings because they can provide nesting and overwintering habitat for bumble bees. Be aware that including grasses can complicate site management if weedy grasses are present because you won't be able to use grass-specific herbicide to control these weeds. If you do include grasses, be sure to avoid sod-forming or creeping species, as these can suppress wildflowers. Grasses do not provide food for bees, so include them at a rate of no more than 25% of the mix.

Plugs, Bare Roots, and Transplants

Drilling holes for transplants at Purple Sage Farm. *Photograph: Jennifer Miller.*

If time is limited but funds are not, already-germinated small plants, or "plugs," can be used to transplant seedlings into the site, helping to jump-start the bloom of a perennial planting. Plugs can be planted into a matrix of mulch or landscape fabric to control weeds.

Transplanting species that can be difficult to establish from seed, such as lupines and some bunchgrasses, can also be a useful addition to a sown wildflower meadow after the first year of mowing for weed management. This approach also works well for adding flowering trees and shrubs along the edges of farm fields.

SEEDING

CHOOSING WHEN AND HOW TO GET SEEDS IN THE GROUND

There are many ways to effectively and efficiently seed a wildflower planting. Here are some of the options and additional considerations to ensure successful germination.

- **Fall seeding.** For native wildflower plantings, fall planting (October – early December) is the best time to seed. Some native wildflower seeds require several months of cold temperatures before they will germinate. By planting in the fall, the seeds will be ready to emerge in the spring. Other species germinate immediately and get a critical head start on weeds. Plant in fall, ideally after the first rains so soils are moist enough to rough up and lightly cover the seeds when sowing.

- **Minimize soil disturbance prior to seeding.** Do not till prior to seeding, as this will bring up weed seeds from the topsoil that will compete with the wildflowers for soil, light, and water. To prepare the soil, lightly rake off debris using a rake or chain harrow to open up areas where seeds can make contact with the soil surface. The seedbed should have at least 50% bare ground for best results. Seeding is best done when the ground is not too moist or muddy.

Broadcast seeding with a hand-operated crank seeder in fall. *Photograph: Logan Rowe, UC Davis.*

Mix wildflower seed with a bulking agent, such as cracked corn or polenta, to help distribute seeds evenly across large areas. *Photograph: Kimiora Ward, UC Davis.*

Seeding a narrow planting with an ATV-mounted seeder and cultipacker. *Photograph: Logan Rowe, UC Davis.*

SEEDING METHODS

Hand broadcast seeding

Seeds can be sown by hand or by using a hand-operated crank seeder or ATV-mounted seed spreader to scatter seeds across the planting area. This low-cost, easy method works best when seeds are mixed with an equal or greater volume of a bulking agent, such as cracked corn, polenta, vermiculite, clay-based cat litter, or seed oats, to help distribute the small volume of seed mix evenly across a large area. Sawdust or coarse sand can also be used if hand-broadcasting seed. Mix seed and bulking agent well. Consider seeding large and small seeds in separate batches. To avoid running out, divide the planting area and seed mix into equal sections. Broadcast half of each batch back and forth horizontally in its section, then seed the remaining half vertically to ensure even spread. It's better to have some seed left over at the end and make another pass over some areas than to run out partway through the planting.

Mechanical seeding

No-till drills or large drop seeders can also be used to seed a planting. These are best used by someone with experience calibrating and operating them. Most conservation district offices have no-till drills available to loan or rent and can connect you with local expertise. With proper calibration, you may not need to add a bulking agent to wildflower seeds for mechanical seeding. Check seed distribution from the drill or drop seeder at regular intervals to ensure that seeds are sown evenly across the planting area. Make sure that you are also able to calibrate the depth at which seeds are sown. Seeds should be sown at very shallow depth to provide seed to soil contact, but without burying them too deep to germinate (no deeper than ¼ inch). It is better to sow seeds too shallow than too deep.

Seeding a wildflower planting with a mechanical drop seeder and cultipacker. *Photograph: Katharina Ullmann, The Xerces Society.*

After seeding

- **Ensure good seed-to-soil contact after planting.** If broadcasting seed by hand or with a drop seeder, use a cultipacker, ring roller, or turf roller to tamp seeds into the top layer of soil after seeding. This will ensure that seeds receive the soil contact needed for germination. Do not disk, harrow, or cover sown seeds with additional soil or mulch; they will germinate best on the soil surface. This step is not necessary if using a no-till drill.

- **Post-seeding irrigation: not recommended.** Most native wildflower plantings in California will germinate and thrive without additional watering after fall rains, because native species are adapted to the locally dry conditions. Weedy species often outcompete natives if plantings are watered. However, limited fall and spring watering can promote wildflower establishment in severe drought years, and infrequent watering (no more than monthly) can extend bloom periods of many species.

POST-SEEDING MAINTENANCE

MANAGING WEEDS AS WILDFLOWERS BEGIN TO GROW

While pre-seeding weed control is the major factor in successful wildflower germination and initial establishment, post-planting maintenance is also critical. This is especially true early in establishment so that wildflowers stay ahead of the weeds. Use care to avoid disturbing soil or small wildflower seedlings, especially if hand pulling weeds.

MAINTENANCE STRATEGIES: YEAR 1

Spring spraying and hand pulling

Controlling weeds in spring of the first year of establishment is critical for ensuring wildflowers successfully take hold and outcompete weedy species. Early in the first season, check the site frequently. If weedy grasses are present in a wildflower-only planting, grass-specific herbicides can be broadcast-sprayed to suppress grasses without damaging wildflowers. Do not broadcast-spray grass-specific herbicide if you have included native grasses in your planting. Grass-specific herbicide is only effective when grasses are small, so it is important to watch your planting carefully in the spring and spray when grasses are four inches tall or less. If problem broadleaf weeds are found in the planting, hand weed or use a backpack sprayer with glyphosate to prevent them from overtaking the wildflowers. Pull or treat weeds before they are large enough or abundant enough to crowd out wildflower seedlings and young plants. Take care to minimize disturbance to wildflower seedlings if possible, but it is better to sacrifice some wildflowers to ensure weed control.

Summer maintenance

If spring weed control was successful, annual wildflowers should have established high native cover, suppressing weeds and allowing perennial wildflowers to establish as spring annuals die back. Check the site monthly for summer-establishing weeds like bindweed, prickly lettuce and marestail. Spot spray, hand-pull or mow to prevent these weeds from setting seed. It is worth sacrificing some wildflower plants to keep weeds from establishing and going to seed in the first year.

If spot spraying or hand pulling leads to patches of bare areas in the planting, consider seeding these areas with wildflowers in the fall or adding plugs to help prevent colonization by more weeds.

LONG-TERM MAINTENANCE

Fall mowing

Annual fall mowing of the wildflower planting can prevent thatch buildup and help maintain species diversity over time. Use a flail mower at the highest setting to protect bee nesting areas.

Reseeding/overseeding

If weeds begin to outcompete the wildflower mix (i.e., more than 75% of the plant cover is weeds by the end of Year 2) or other factors led to poor establishment, you may need to spray out some areas and reseed. In later years perennial wildflower species can dominate and you may want to overseed annuals

to restore the original wildflower diversity. Unless you want to restart site preparation and reseed at the original rate, use overseeding to fill in gaps in the planting. Use a rake or light chain harrow to open up some areas of bare soil, then seed the wildflower mix in those areas in late fall. Do not till, as this will disturb wildflower seedlings and bring additional weed seeds to the surface. Consult with a local restoration or plant expert in the first two years to determine how the planting is progressing and whether any additional action is needed.

Avoid insecticides

Avoid spraying insecticides on or near plantings to ensure that pollinators supported by the plantings are not killed by exposure to these chemicals. To learn more, see the Pacific Northwest Extension publication "How to Reduce Bee Poisoning from Pesticides" (*https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw591.pdf*). The UC IPM Bee precaution pesticide ratings website provides pesticide-specific guidance to reduce bee poisoning (*https://www2.ipm.ucanr.edu/beeprecaution/*).

Manage planting borders to prevent weed encroachment

If weeds are allowed to flower and go to seed around or near the edges of plantings, they will invade and compete with the native wildflowers in the plot. Mow or apply herbicide regularly around the edge of the planting to keep these edge weeds under control, and to provide a burn break if needed. Consider a wider border of control for wind-dispersed weeds like prickly lettuce and marestail.

Some weeds are beneficial!

Many flowering weeds also provide pollen and nectar resources to pollinators, and can coexist with wildflowers in the planting to provide these resources. Consult with local plant experts and check the list of Common Problem Weeds (*Appendix 2*) to help determine whether the weeds present in your planting present a long-term threat to successful pollinator habitat.

WHAT SHOULD I EXPECT MY PLANTING TO LOOK LIKE OVER TIME?

Establishing long term pollinator habitat from seed requires time and patience.

California wildflower plantings provide critical resources for bees when there is little else blooming in the landscape. *Photograph: Jessa Kay Cruz, The Xerces Society.*

Successful wildflower plantings in the California Central Valley can be thick with flowers in spring and early summer but may look dry and sparse in midsummer until sunflowers and gumplant begin to bloom. Despite their appearance these plantings do have flowering plants (e.g. *Clarkia*, California poppy, and California phacelia) at this time of year and provide critical resources for bees when there is little else blooming in the landscape. It can be helpful to place a "pollinator habitat" sign at the edge of the planting to highlight that this is a deliberate planting.

In the second and third years, spring-flowering annuals might become more sparse as the perennials take up more space. You may consider overseeding annuals to restore diversity in the third year.

Wildflower plantings placed near pollinator-dependent crops can boost crop yields by enhancing wild pollinator populations. These plantings also supply pollen and nectar for managed honey bees. *Photograph: Jessa Kay Cruz, The Xerces Society.*

COSTS AND BENEFITS

Wildflower plantings can seem expensive if you consider only the costs of establishment, including the cost of wildflower seed and labor to prepare and manage plantings. Depending on the seed mix and the materials and labor needs for weed control, establishment can cost from several hundred to a few thousand dollars per acre. However, these plantings provide benefits as well, and there are cost-share programs available from the US Department of Agriculture (USDA) as well as non-federal agencies. Tracking yields for four years in Michigan highbush blueberry fields with or without adjacent pollinator plantings revealed that the initial cost of the plantings was recouped by the higher yields of blueberries in those fields. There is evidence that plantings may increase density of watermelon fruits in crop fields which would increase yield, but the return on investment has not been tracked for this or other California row crops, and may vary depending on how well the planting establishes, as well as how dependent the crop is on insect pollinators for better yields and larger fruit. It is encouraging that for California the pollination benefit is achieved in the first season post establishment.

SUMMARY

Many pollinators of California row crops require flowers for food through the growing season. Wildflower plantings are one strategy to provide these resources on your farm and build populations of wild bees. Wild bees can complement honey bees, help ensure high yields, and reduce the risk of poor pollination. Additional strategies include planting shrubs, and growing flowering cover crops. Wildflower plantings will take time to establish and may have a "messy" stage in some seasons, but yield benefits may make up for these initial costs.

APPENDIX 1: ADDITIONAL RESOURCES

Plant experts:

For more information on and assistance with designing a mix specific to your local area and soil conditions, consult native plant and habitat restoration experts in your area. Check with native plant producers in your area (*http://www.calscape.org/plant_nursery.php*), your local USDA Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) office (*https://offices.sc.egov.usda.gov/locator/app*), and non-profits like the Xerces Society for Invertebrate Conservation (*http://www.xerces.org*).

Bee conservation & habitat:

Vaughan, M., J. Hopwood, E. Lee-Mäder, M. Shepherd, C. Kremen, A. Stine, & S. H. Black. 2015 (4th ed). *Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms*. 84 pp. Portland, OR: The Xerces Society for Invertebrate Conservation.

US Department of Agriculture. 2015. *Using 2014 Farm Bill Programs for Pollinator Conservation*. Biology Technical Note No. 78, 3rd ed. 18 pp. Available: http://bit.do/2014-farm-bill-programs

Pollinator Conservation Resource Center (The Xerces Society for Invertebrate Conservation): http://www.xerces.org/pollinator-resource-center/

Site preparation and weed management:

Weed Research & Information Center, University of California, Davis: http://wric.ucdavis.edu/

Foltz Jordan, S., J. Kay Cruz, K. Gill, J. Hopwood, J. Fowler, E. Lee-Mäder, & M. Vaughan. 2017. *Organic Site Preparation for Wildflower Establishment*. 42pp. Portland, OR: The Xerces Society for Invertebrate Conservation. Available: http://xerces.org/guidelines-organic-site-preparation/

Pesticide safety

Bee Precaution Pesticide Ratings, University of California Agriculture & Natural Resources Statewide Integrated Pest Management Program (UC IPM). Available: http://www2.ipm.ucanr.edu/beeprecaution/

Johansen, E., L. A. Hooven, and R. R. Sagili. 2013. *How to Reduce Bee Poisoning from Pesticides.* Oregon State University. Available: http://bit.do/reduce-bee-risk

Code, A., H. Sardinas, T. Heidel-Baker, J. K. Cruz, S. H. Black, E. Lee-Mäder, M. Vaughan, & J. Hopwood. 2016. *Guidance to Protect Habitat from Pesticide Contamination.* Portland, OR: The Xerces Society for Invertebrate Conservation. Available: http://bit.do/habitat-contamination

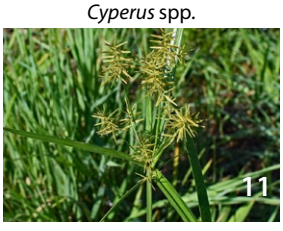
Integrated Crop Pollination

Crop-specific resources can be found at http://projecticp.org/tools-for-growers/. Visit the Project ICP Youtube channel at http://bit.do/ICP-youtube for videos on pollination and habitat restoration.

APPENDIX 2: COMMON PROBLEM WEEDS

DEALBREAKER WEEDS

These weed species require aggressive management for control. If your selected site has any of the listed species present in abundance, consider selecting a different site. If no other site is feasible, consult with local Extension or weed experts to create a plan for effective management; these species may require two or more seasons of weed control prior to seeding.

	DESCRIPTION	HOW TO CONTROL	FOLIAGE
Field bindweed *Convolvulus arvensis* 	Hardy perennial with extensive root and rhizome system that allows plant to regrow from root fragments as short as 2 inches long. Drought tolerant.	Tillage of young seedlings can be effective, but after 3-4 weeks of growth cultivation is no longer effective. Till every 2-3 weeks for best results. Repeated applications of herbicides can suppress but generally will not eliminate bindweed. Solarization will not control bindweed with its deep system of rhizomes. See *http://bit.do/bindweed*	
Mallows *Malva* spp. 	Annual or biennial plants 2-5 feet tall with lily-pad-like round leaves and deep woody taproot. Germinates in fall and produces seed in as little as 15 days.	Very difficult to remove after seedling stage because of deep woody taproot. Glyphosate alone can be ineffective when plants are large; tank mixes with Shark (carfentrazone-ehtyl) perform better. See *http://bit.do/mallow*	
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 does not reliably control hairy vetch; best control is achieved when mixed with Shark (carfentrazone-ethyl) and sprayed in the spring when the plants are small. Solarization does not kill the hard seeds 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 slightly heart-shaped or arrow-shaped.	This plant is difficult to control when mature. Spray with glyphosate at the seedling stage. Solarization is effective. See *http://bit.do/fluvellin*	
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 control with glyphosate is in the early seedling stage before the plant becomes hardened off. Solarization is effective. See *http://bit.do/CAknotweed*	
Nutsedge *Cyperus* spp. 	Perennial sedge plants that thrive in moist, poorly drained soils. Produce underground tubers and rhizomes that will sprout new plants.	Tilling mature plants will worsen infestations; till small plants every 2-3 weeks to limit tuber production. Solarization can be effective. Most herbicides are not effective against tubers; repeated glyphosate applications will suppress but not eliminate nutsedge. See *http://bit.do/nutsedge*	

OTHER PROBLEM WEEDS

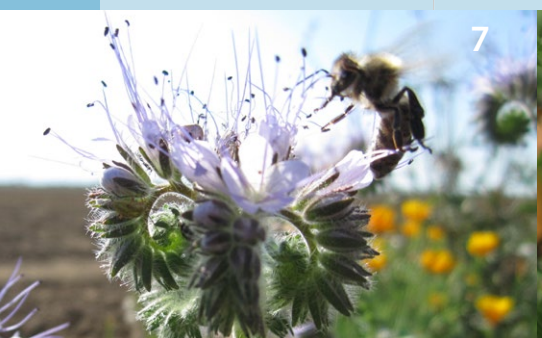
	DESCRIPTION	HOW TO CONTROL	FOLIAGE
Mustards Brassicaceae family 	Winter or summer annual broadleaf plants, sometimes biennials. Can form dense patches that outcompete wildflowers. *Brassica nigra* (spring), *Sinapis arvensis* (sprinng) and *Hirschfeldia incana* (summer) can all become problems in CA plantings.	Manual removal or cultivation before seeds develop (at seedling stage) can control populations. Mowing during bud to bloom stage can suppress seed production. Several postemergent herbicides are effective for control.	
Prickly lettuce *Lactuca serriola* 	Annual or biennial with deep taproot. Leaves and stems emit a milky sap. Common in disturbed sites.	Manual removal of seedlings before taproots develop is effective. Some populations have developed glyphosate resistance, but there are other effective postemergent herbicides. Mowing provides poor control.	
Filaree *Erodium* spp. 	Low-growing winter annual and sometimes biennial broadleaf plants. Young plants form a dense rosette at the soil surface. Seeds can remain viable for many years in the soil.	Manual removal or cultivation before fruits develop can help suppress filaree populations. Burning tends to increase abundance of filaree. Several herbicides are effective; see *http://bit.do/erodiumcontrol* for more detailed information.	
Hairy fleabane and marestail *Conyza* spp. 	Summer annual or biennial broadleaf plants common in disturbed and/or cultivated areas. Highly competitive for resources and can suppress germination of wildflower seeds when present. Prolific seed producers.	Tillage or herbicide control of seedlings can be effective. Mowing is generally not effective. Both *Conyza* species have strains resistant to glyphosate; contact your local Extension office for the best method of control. See *https://anrcatalog.ucanr.edu/pdf/8314.pdf* for more.	
Willowherb *Epilobium brachycarpum* 	Native broadleaf plant that can be weedy in disturbed areas. Can grow to around six feet in height. Reproduces by seed.	Solarization can be effective. Glyphosate alone is generally not effective for control of willowherb. Contact your local Extension office for control recommendations.	
Yellow starthistle *Centaurea solstitialis* 	Long-lived winter annual that is highly competitive in sunny disturbed areas. Does not compete well in low-light environments. Seed can be spread by vehicles.	Tillage, mowing, and grazing can be effective. Several postemergent herbicides can provide effective control. Biological control agents are available; contact local Extension for more information. See *http://ipm.ucanr.edu/PMG/PESTNOTES/pn7402.html.*	

Photo Credits

1: Tony Atkins; 2: Frank Mayfield; 3: Jean-Luc Miard; 4,18,20: Forest & Kim Starr; 5: Kristian Peters; 6: Harry Rose; 7,8: Augustin Roche; 9,23,24: Matt Lavin; 10,12: NY State IPM Program at Cornell; 11: Jan Haerer; 13,19: Rasbak (Wikimedia); 14: Michael Plagens; 15: Andreas Rockstein; 16: F.D. Richards; 17: Ivanhoe65 (Wikimedia); 21: PePeEfe (Wikimedia); 22: Alberto Salguero. Photos licensed under Creative Commons attribution except where denoted by *.

APPENDIX 3: RECOMMENDED PLANT LIST

	Common Name	Scientific Name	Life History	Seeding Rate	Percent of Mix
FORBS			Annual / Perennial	Pounds per acre	% bulk seeds per sq ft.
1	Great Valley phacelia	*Phacelia ciliata*	A	1.04	10%
2	Arroyo lupine	*Lupinus succulentus*	A	9.18	4%
3	Baby blue eyes	*Nemophila menziesii*	A	1.07	14%
4	Chick lupine	*Lupinus densiflorus*	A	5.46	2%
5	Chinese houses	*Collinsia heterophylla*	A	0.96	14%
6	Lacy phacelia	*Phacelia tanacetifolia*	A	0.40	3%
7	California phacelia	*Phacelia californica*	P	0.48	6%
8	California poppy	*Eschscholzia californica*	A, P	0.63	7%
9	Fort Miller clarkia	*Clarkia williamsonii*	A	0.20	10%
10	Elegant clarkia	*Clarkia unguiculata*	A	0.14	10%
11	Valley gumplant	*Grindelia camporum*	P	0.63	4%
12	Vinegarweed	*Trichostema lanceolatum*	A	2.11	16%



BLOOM PERIOD

Bloom times will vary by year and location. Suggested seeding rate is based on 50 live seeds/sq ft.

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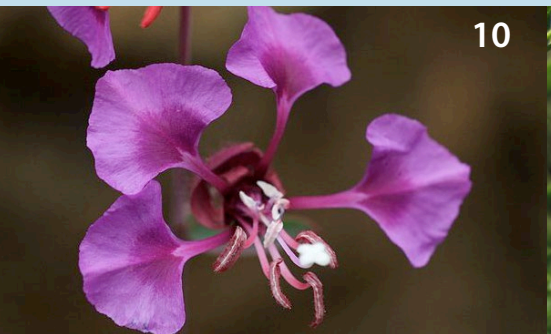

A yellow-faced bumble bee (*Bombus vosnesenskii*) visiting California poppy (*Eschscholzia californica*). Many bees that pollinate California row crops, including wild bees and honey bees, benefit from the pollen and nectar provided by nearby wildflowers. Photograph: Mace Vaughan (The Xerces Society).

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