COVER CROP

BEST MANAGEMENT PRACTICES

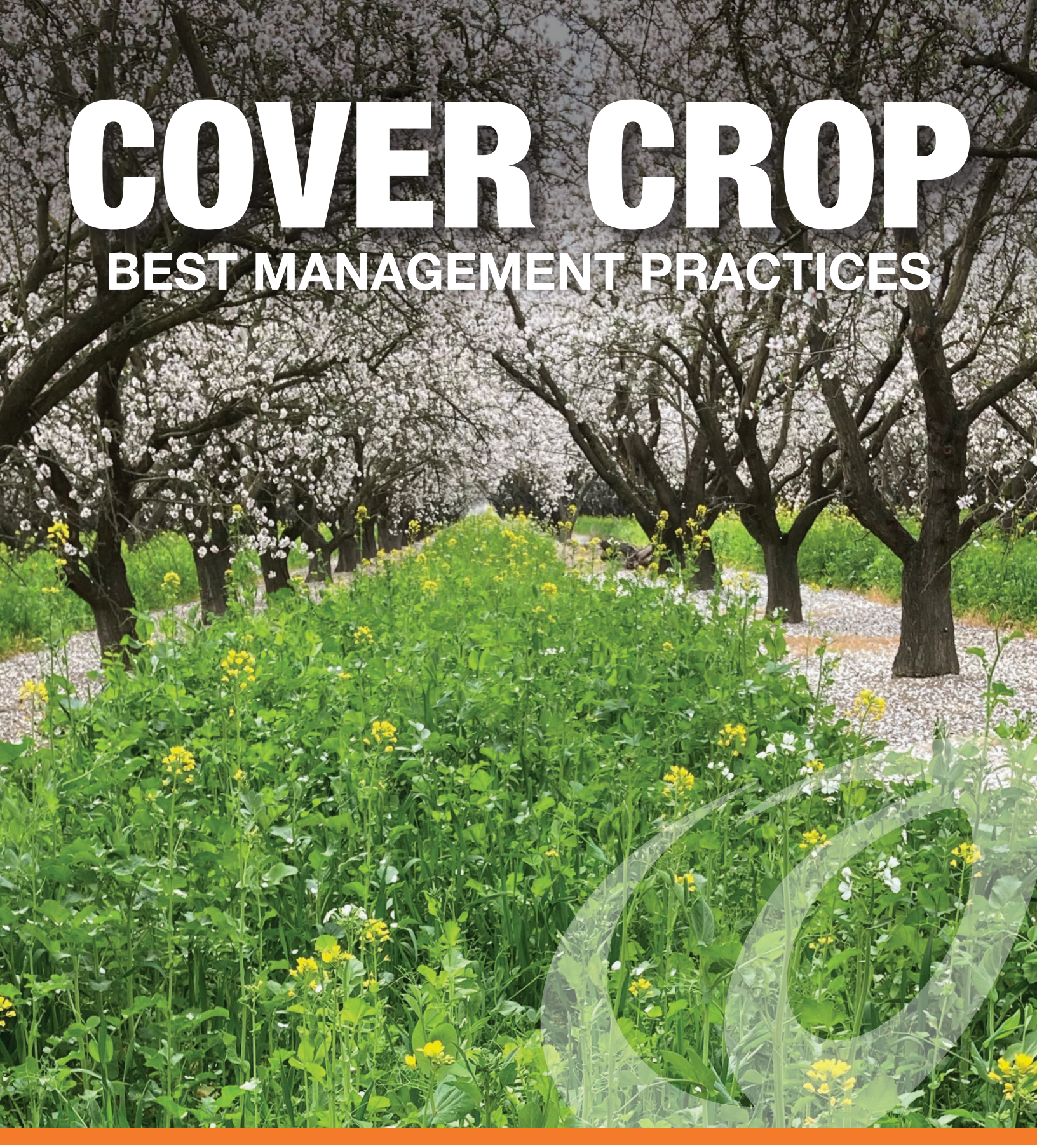

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TABLE OF CONTENTS

Why Cover Crops	**2**
Cover Crop Best Management Practices	**3**
Step 1: Planning	**5**
Step 2: Planting	**9**
Step 3: Growth	**11**
Step 4: Termination	**14**
Step 5: Post-Termination Until Harvest	**16**
Additional Cover Cropping Strategies	**17**
Additional Resources	**19**
References	**22**

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Brassicas can be an important source of pollen and nectar for bees.

WHY COVER CROPS

Cover crops and resident vegetation can provide enhanced agronomic and ecosystem benefits to California almond orchards. Management and site-specific factors will determine if, when, and how cover crops will fit into a specific orchard system.

Depending on the circumstances, cover crops or resident vegetation have the potential to help growers accomplish a wide range of goals, from desired improvements to reductions in on-farm challenges.

No single cover crop will accomplish all these goals at once. Fellow growers, University of California Cooperative Extension (UCCE) farm advisers, crop and pest advisers, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and the broader research community are all important allies in determining when and how to use cover crops to accomplish your goals. Further, research funded by the Almond Board of California (ABC), California Department of Food and Agriculture (CDFA), USDA and other organizations throughout the state continues to define and refine the best practices for cover crops use in almonds.

POTENTIAL GOALS

- enhance pollinator forage
- enhance beneficial insects
- suppress pest nematodes
- improve water infiltration
- improve orchard access during winter and spring rains
- reduce compaction and cracking
- reduce erosion
- manage salinity and sodicity
- reduce nitrogen losses
- increase soil nitrogen
- support soil biology
- increase soil carbon and organic matter
- manage weeds

COVER CROP BEST MANAGEMENT PRACTICES

The fundamental element of cover crop management in almonds is to fit cover crops into your orchard system in a way that works for you. For most growers, that means planting winter cover crops, which is the focus of this guide.

It is most important for winter cover crops to be planted after harvest when irrigation or rainfall is available to support germination and establishment. Then, growers should aim to leave the crop alive as long as possible within the context of other orchard needs and management goals. Ultimately, individual orchard conditions will require adaptation of these best management practices.

How do you get started?

1. Plan ahead and start small.

   Use the five major management stages (explained in detail below) as your guide:

   - **Step 1:** Planning
   - **Step 2:** Planting
   - **Step 3:** Growth
   - **Step 4:** Termination
   - **Step 5:** Post-Termination Until Harvest

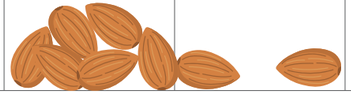
2. Scale up using available resources while taking orchard conditions into account. Adjust the management practices that work best in your orchard(s) based on your observations and experience.

3. Find fellow growers, advisers and/or researchers with whom to compare results and brainstorm innovations and adaptations.

Remember, in many cases, recommendations may change as more research, experimentation and observations take place.

Timing of Cover Crop Management in Almonds

	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Planning	Evaluate cover crop strategy and consider where to plant											
	Talk to other growers and look into funding options											
		Select and order seeds										
		Choose seeding and termination equipment										
Planting				Prep soil, as necessary, for planting								
				Plant cover crop within two weeks of predicted rain and/or irrigate, if possible, for establishment								
Growth				Shake mummies and prune over cover crops or in alternate rows (you can grind prunings and mummies in non-cover crop rows, or before planting the cover crop)								
						Monitor for pests (gophers and insects) as they emerge in the spring						
							Mow if facing frost risk: <2 inches will terminate the cover crop, depending on species					
							High mow (>6 inches) to manage winter weeds, allow slow-growing species more light, and to keep vegetation lower and younger					
								If cover crops flower, avoid spraying during the daytime when insects are active				
Termination								Early season termination	Mid-season termination	Late-season termination		
Post-Termination Until Harvest										Mow to break down residue and control weeds (may need to mow multiple times)		
										Irrigate lightly, if possible, to aid in residue breakdown		



STEP 1: PLANNING

Before the cover crop is seeded, it is important to clearly define your goals and the orchard-specific circumstances into which you will be planting. Answer the following questions before purchasing and planting seeds to set yourself up for greater success.

What is the primary purpose of the cover crop? What problems are you trying to address or what improvements do you want to make?

Cover crops, like any other tool in your orchard, will be managed based on your goals, outlined on page 2. Goals may include achieving benefits such as adding nitrogen to the soil and addressing challenges such as reducing erosion.

What age is your orchard?

Choosing the right cover crop species or mix will depend on orchard age due to changes in potential for competition with trees and canopy coverage.

Each of the major orchard phases provides distinct opportunities and considerations to incorporate cover crops:

Fallow field before (re)planting

- Combat nematode issues and/or build soil organic matter (depending on species) before orchard replant.
- In orchards that are being planted after Whole Orchard Recycling[1] has taken place, cover crops may regulate soil moisture conditions, support microbial processing of orchard residue and mitigate nitrogen immobilization.

First- and second-leaf orchard

- **Benefit:** Opportunity to grow high biomass cover crops with ample sunlight and terminate without the need to manage residue decomposition prior to harvest.
- **Consideration:** Ensure that cover crops do not compete with trees for resources.

Pre-canopy closure orchard

- **Benefit:** Opportunity to grow large cover crops with ample sunlight.
- **Consideration:** Ensure cover crops do not compete with young trees and that residue does not impede harvest.

Mature orchard

- **Benefit:** Choose species based on goals, such as legumes for nitrogen, grasses for high biomass, or brassicas for early flowers.
- **Consideration:** Ensure that cover crop residue does not impede harvest.

Be prepared to adjust your cover crop mix and management to match your goals and experience over the life of your orchard(s).

This brassica cover crop in Stanislaus County was broadcast seeded in mid-November and irrigated at the same time as the trees.

What kind of irrigation is available?

Microsprinklers, solid set sprinklers, flood irrigation: If there is no rain near planting time, monitoring of germination is required and irrigation may be essential to support the cover crop. Rainfall of two inches is enough to germinate a cover crop,[2] but species vary as to the amount of moisture they require. While the irrigation system may not have full coverage, any irrigation system that reaches the orchard middles will support stand establishment and higher biomass.

Drip irrigation: In the absence of irrigation that reaches the orchard middles, cover crops must rely on rainfall. Cover crop species selection should therefore be limited to species that are more tolerant to dry conditions[3] and should:

1. be planted when there is forecasted precipitation within two weeks, or
2. be expected to germinate less evenly if seeded more than two weeks before a rain event.

Some regions of the state may not receive sufficient winter precipitation early enough in the growing season to successfully grow cover crops during dormancy. However, growers in those regions may be able to grow a cover crop in early spring. Keep in mind that pollinator forage and weed suppression benefits are particularly dependent on prompt establishment.

Is your orchard organic?

Organic growers will need to look for certified organic cover crop seed with organic certified seeding coating, when appropriate, and may rely more on cover crops to provide sufficient nitrogen. In such cases, legume-heavy cover crops may be particularly useful. Organic growers should also be particularly proactive about termination plans to maximize nitrogen contributions.

Are there any specific pest concerns?

Pest pressures and pest vulnerabilities of neighboring crops should be considered during the cover crop species selection and management process. Gaining familiarity with Integrated Pest Management (IPM) approaches before implementing cover crops will also facilitate success. Monitoring of pests is also a key aspect to mitigate possible negative effects of cover crops on pest management. This practice allows growers to optimize IPM benefits, such as augmentation of beneficial predators and parasitic insects, which can help control pest populations. The BIOS Manual for Almonds offers additional guidance on cover crops and IPM strategies.[4]

Research shows that owls may prove helpful in managing rodents.

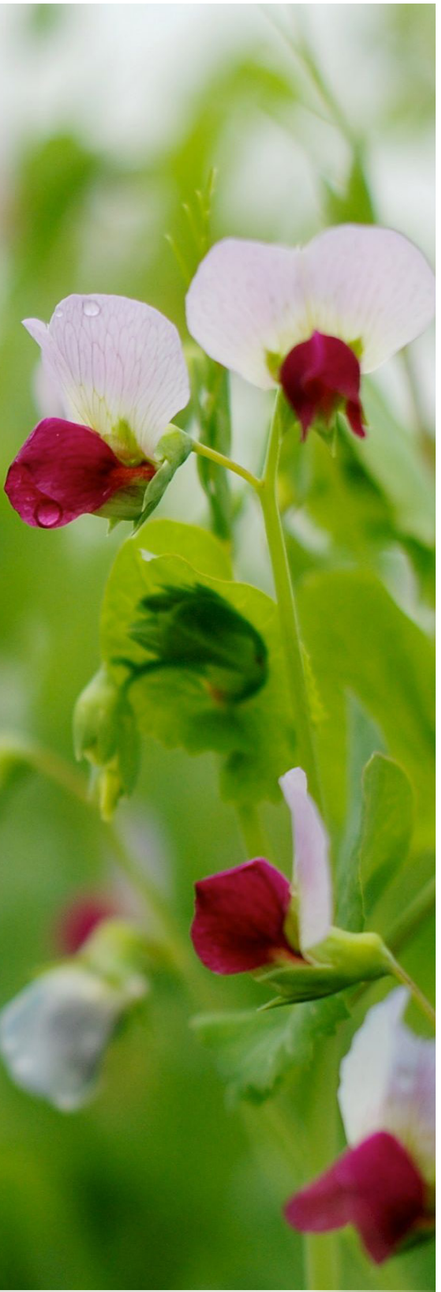
Gopher activity in orchard row.

Gopher pressure can be increased by cover crops because the crop biomass provides a food source and may hide gopher signs. The risk of increased rodent pressure is higher in young orchards because rodents can kill young trees. You may choose to limit inclusion of legumes, particularly clovers, because of rodent preference for these species, though site-specific factors will affect rodent population pressure and preference.[5] Careful and consistent monitoring is important, along with proactive control of any emergent gopher problems. Additional strategies, such as owl boxes, show potential as part of a whole-farm management strategy for rodents,[6] and on-farm guidance for their use is available for growers.[7]

Adjacent susceptible crops should influence cover crop species selection. Multiple cover crops can host pest insects such as lygus, flea beetles and cucumber beetles and should be avoided in orchards that are adjacent to susceptible crops.

Current research is testing the effects of cover crop mixes on **orchards infested with nematodes.**[8] Planting cover crops with the management goal to suppress pest nematodes requires particular attention to species selection, orchard age, and termination methods, and may be well-suited to orchard re-plant scenarios. For instance, a brassica cover crop seeded on a fallow orchard after the trees have been removed could provide biomass for active biofumigation when the cover crop is tilled into the soil after termination and the soil is kept moist. Even when planted into an existing orchard, brassica cover crops may provide some nematocidal effects.

The current best practice to maximize the effectiveness of biofumigation is to terminate the cover crop, break up the residue as much as possible and incorporate it into the soil while still fresh. Fine shredding of the material is particularly important as it maximizes opportunities for contact of the plant-contained biochemicals that affect biofumigation. Because breakdown of biofumigation compounds decreases as soil temperatures decrease, biofumigation should be planned for warmer months.



Austrian winter pea, shown here in bloom, can provide a good source of nitrogen to the orchard. Photo courtesy of JiJy Thanwalee Sooksa-Nguan

STEP 1: PLANNING (CONTINUED)

What are the appropriate species to meet your goals?

Species selection can be a complex element of cover crop use because there are multiple potential species and mixes from which to choose. Ultimately, the best combination of species depends on your goals and orchard needs, as shown in the four examples on page 8. You should work with your seed salesperson, crop adviser, and/or UCCE adviser to choose species that will meet your orchard's needs.

Five major classes of cover crop species are used in almonds, with the first three being most common in cover crop literature. Different types can also be combined to balance tradeoffs or layer benefits:

Grasses:

- used for root benefits to the soil and aboveground biomass accumulation
- higher carbon-to-nitrogen (C:N) ratio may slow decomposition; however, prompt germination can provide weed suppression benefits

Legumes:

- provide additional nitrogen
- flowers for pollinators
- generally low C:N allows for relatively quick decomposition
- low-growing clovers may work best in high frost risk areas

Brassicas:

- quick-growing
- generally used to provide flowers for pollinators and suppress some nematode species
- some species have large tap roots that create large root channels, which can result in soil benefits
- easy decomposition if terminated before they dry out; otherwise, can be woody and decompose slowly, and may contribute to the seedbank

Other annuals:

- usually in almonds these will be native species, which are planted for their flowers to enhance insect forage
- can provide weed suppression and soil benefits

Perennial cover crop species and annual re-seeding:

- any of the species types above when managed to set seed before termination
- may reduce seed cost but requires distinct management (discussed in "Additional cover cropping strategies" section)

Most cover crop species used in almonds are "cool-season" crops that are planted after almond harvest, thrive in the winter and spring, and are terminated before summer to decompose ahead of the following harvest. As such, most cover crops will take advantage of winter rain and complete most of their life cycle while the almond trees are dormant, thus reducing concerns of direct competition between the tree and the cover crop. However, cover crop species differ in how much time they need to reach maturity and provide maximum benefit. In addition to commercially bred cover crop species, native species are typically used for flowering capability because they are well-adapted to the California climate and can thrive with less water than cultivated species.

COVER CROP MIX EXAMPLES

Project Apis m. Brassica Mix

Seeding rate: 8-12 lbs/acre

Canola	35%
Bracco White Mustard	15%
Nemfix Yellow Mustard	15%
Daikon Radish	20%
Common Yellow Mustard	15%

Well-suited to enhance pollinator forage, benefical insect habitat and forage, and suppress nematodes. Note timing requirements if your goals include supplemental pollinator forage before or during almond bloom.

Photo courtesy of Project Apis m.

Commerical Seed Mix 1

Seeding rate: 50-120 lbs/acre

Cayuse Oats	23%
Pacheco Triticale	7%
Nitroplex Peas	15%
Dundale Peas	15%
Bell Beans	36%
Canola	1%
Daikon Radish	1%
Common Yellow Mustard	1%
Nemagon White Mustard	1%

Well-suited to balance goals to add nitrogen and high biomass for building soil organic matter and promoting carbon sequestration. Includes brassicas to provide floral resources. Note timing requirements if your goals include supplemental pollinator forage before or during almond bloom.

Photo courtesy of Frank Olagaray

Project Apis m. Clover Mix

Seeding rate: 15-25 lbs/acre

Balansa Clover	17%
Persian Clover	25%
Hykon Rose Clover	8%
Crimson Clover	10%
Medic (Burr or Barrel)	15%
Berseem Clover	25%

Well-suited to an orchard where taller cover crops are a concern. Will add nitrogen to the soil and is easy to mow. Not suitable for areas with annual rainfall of <12 inches.

Photo courtesy of Project Apis m.

Commerical Mix 2

Seeding rate: 100 lbs/acre

Bell Beans/Fava	40-50%
Forage Peas	30-40%
Common Vetch	10%
Small Grain (Oat, Triticale, Barley)	10-15%

Well-suited to provide ample nitrogen and high biomass (up to 10,000 lbs biomass and 100-150 lbs fixed nitrogen).

Photo courtesy of Tom Kamprath

STEP 2: PLANTING

Equipment

Seeders and mowers are often available to rent from seed suppliers, chemical companies or from Resource Conservation District field offices, depending on your region and operation size. You can also hire a custom seeder or mower, or use machinery from other crops.

Each piece of equipment will need to be calibrated according to the seed mix you are planting. This is particularly important for mixes with different size seeds, which may require multiple seeding passes.

Equipment will determine your options for planting width, along with orchard spacing. Most growers plant a 6-to-12-foot strip in the middles, leaving the tree row free of vegetation.

Broadcasters work best for cover crops with small seeds. The soils may need to be loosened prior to planting, and seed incorporated, rolled, or cultipacked to provide seed-to-soil contact after planting.

Photo courtesy of Ted Reimers

Grain drills facilitate seed-to-soil contact but work best with a prepared seedbed, and for some species will require a second box for small seeds.

Photo courtesy of Project Apis m.

No-till drills, which will maximize germination, are the most precise and expensive seeding method for cover crops.

Photo courtesy of Project Apis m.

Timing

Growers should seed cover crops after harvest and post-harvest levelling of the orchard middles. The widest range of benefits will be possible if seeding is completed prior to tree irrigation (for microsprinkler and flood irrigation) or prior to rain (for drip-irrigated systems).

Seeding before December is typical for cover crops to allow adequate soil temperatures to germinate reliably, and to have time to establish and grow. Short day length in December and January, along with colder temperatures, are most limiting for cover crop growth. Earlier seeding (depending on water availability) will result in larger plants, more complete ground cover, and greater likelihood of timely flowering. However, seeding when there is available water is most important, and later seeding in late winter or early spring as day length increases may still produce a cover crop that can meet your goals.

IF YOU WANT TO…

Enhance pollinator forage, brassica cover crops must be seeded by mid-October and irrigated to reliably blossom before almond bloom. Other species are unlikely to bloom before almonds irrespective of planting time. In the absence of irrigation and/or with later planting, cover crops will generally not germinate in time to provide forage for bees before almond bloom but can still promote bee health[9] by providing additional forage during and after almond bloom.

Manage weeds, one of the best ways to increase the competitive ability of any crop is rapid germination and establishment. Seeding into the soil with adequate temperature and moisture conditions, preferably after existing weeds have been managed, will give the cover crop a head start on any later-germinating weeds. Growers should seed before soil temperatures drop below 50F°. Cover crops germinate slower in cooler soils and will be less likely to outcompete weeds.

Seeding Rate

The seed mix examples found on page 8 include recommended seeding rates. The seeding rate for your cover crop may differ from these examples based on several factors:

- Less-than-ideal seeding conditions may require higher seeding rates to compensate for potentially low germination.
- Some growers choose lower seeding rates to reduce cover crop costs.
- Some cover crop benefits, such as weed suppression, are more difficult to obtain with lower seeding rates.
- Higher seeding rates are more likely to result in a good cover crop stand, but germination (or rainfall or irrigation) is also a major determinant.

Information on seed sources and potential funding for cover crops are included in the "Resources" section at the end of this guide.

Planting Options to Facilitate Winter Orchard Maintenance

Many growers express concern about how winter cover crops may impact their ability to perform orchard maintenance such as pruning, winter sanitation, and dormant or bloom sprays. Ongoing UCCE research projects conducted throughout California are looking at the impact of cover crops on winter sanitation practices.

Cover crops can be managed in such a way that winter sanitation may still take place. Four planting practices that growers and researchers have found successful include:

Every row: Seed all rows after winter maintenance. Mow or drive over some rows, as necessary, with the expectation that they will produce less biomass. Mummy shredding will terminate the cover crop.

Alternate row: Leave half of the rows unseeded as "working rows" and limit traffic and sanitation operations to these rows. Resident vegetation can be maintained in the working rows.

Offset planting time: Seed working rows later than non-working rows, after most of the winter orchard work (pruning, mummy shaking, and shredding) is completed.

Low-growing: Seed low-growing species (like clover) that are easier to drive over while keeping the soil covered.

WHAT YOU SEED IS NOT (NECESSARILY) WHAT YOU GET.

Your actual cover crop stand will vary depending on the relative germination of species, which is affected by seedbed preparation, seeding method, and seeding rate, as well as soil texture, temperature, and available moisture. This is why, even though monocultures are options, seed mixes often include what may seem to be redundancies (multiple types of clover, for example). Diversity and redundancy are tools in cover cropping that give you the greatest chance for success and maximum benefit.

STEP 3: GROWTH

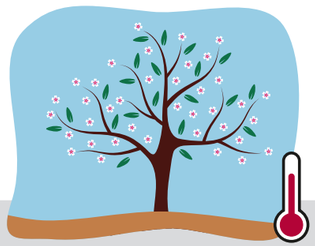
During cover crop growth, there are multiple management decisions that can enhance the benefits of cover crops and mitigate tradeoffs. The main concerns that growers have about cover crops and how to mitigate tradeoffs are summarized in the following table.

MAIN CONCERNS	MITIGATION STRATEGIES	
	Management options	Species selection
Excess water use	Seed with rain and terminate promptly when rains end	Check with seed supplier for species that will do well given your water availability
Frost damage	Mowing <2 inches will terminate most cover crops. A higher mow will not terminate the cover crop but may not increase soil temperature.	Low-growing and will grow back after mowing
NOW control	Use alternate rows for cover crops and winter sanitation, or mow cover crop to destroy mummies	Species selection will not impact mummy management
Increased pest incidence	Terminate before cover crop maturity and monitor for pests of concern	Choose based on specific pest
Harvest complications	Terminate when cover crops flower, mow multiple times, irrigate, and/or chemical mow pre-harvest	Start by planting legume-heavy mixes, and add more grasses and brassicas with more experience

Irrigation

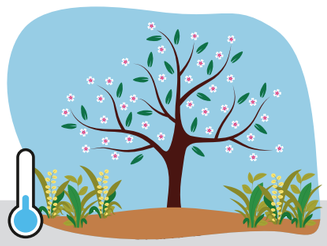
Cover crops often do not require irrigation after establishment, though they consume water from winter precipitation. Overall, their impact on soil moisture can be negligible because bare soil also consumes water through evaporation and runoff.[10]

Because cover crops improve soil health and structure, they may bring additional benefits such as increasing soil water infiltration and retention from winter precipitation, along with other above- and belowground benefits. Growers should monitor soil moisture or tree stress to minimize water competition stress. Additionally, termination of the cover crop at the end of the rainy season will limit consumptive water use. To be most effective at limiting soil moisture loss, you should plan ahead based on projected weather patterns and terminate your cover crop before a moderate rainfall event. This will minimize soil moisture depletion so that it will be similar to a bare orchard at the end of the season. Do not terminate the cover crop after moderate rainfall, as this will lead to compaction and future problems.



Water Use of Bare Soil

- Soil water evaporation
- Increased soil temperature
- Lower soil water infiltration
- Soil surface sealing and runnoff



Water Benefits from Cover Crops

- Transpiration via cover crop canopy
- Cooler surface temperature
- Increased soil water infiltration
- Dew moisture collection by cover crop canopy

Pollination

Almond Board-funded research suggests that **cover crop presence does not lead to decreased yield associated with competition for pollination between trees and cover crops.**[11] **In fact, cover crops have demonstrated benefits for bee health.** Additionally, wildflower plantings adjacent to cover crops do not compete with almond blossoms for bee visitation.[12] Growers should refer to the Almond Board of California's Honey Bee Best Management Practices[13] to learn more about ensuring pollinator health, particularly in regard to avoiding sprays during the day when bees are present, avoiding tank mixes, and not adding adjuvants unless specifically called for on the label.

To maximize the presence of beneficial insects and native pollinators, try to provide additional permanent and well-protected habitat so that pollinators and beneficials have somewhere to disperse to when cover crops are mowed.

In general, orchards with supplemental forage plantings tend to have higher nut set than those without plantings.[15]

Integrated Pest Management

Cover crops have been shown to harbor populations of beneficial insect predators,[16] though timing of cover crop termination and/or the pest life cycle may limit the extent to which cover crops augment biological control.

If possible, spraying for insect or disease management should be avoided during cover crop growth to retain potential IPM benefits. Cover crops may also interfere with winter sanitation of mummy nuts, a key strategy for management of navel orangeworm. Ease of sanitation will depend on seeding decisions, as outlined in the "Planting options to facilitate winter orchard maintenance" section. If you are planting every row, note that orchard sanitation should be carried out in the fall prior to cover crop emergence. Otherwise, you should plan on terminating the cover crop early (February to mid-March) to shred mummy nuts.

BEE PRECAUTION PESTICIDE RATINGS[14]

These ratings provide guidance on how to reduce bee poisoning. They are based on reported pesticide effects on adults and brood of honey bees and other bee species. Ratings are for the pesticide active ingredient, the common name.

I Do not apply, or allow the application to drift to plants that are flowering, including weeds. Do not allow the pesticide to contaminate water accessible to bees, including puddles.

II Do not apply or allow the application to drift to plants that are flowering, including weeds. The only exception is when the application is made between sunset and midnight, if allowed by the pesticide label and regulations. Do not allow the pesticide to contaminate water accessible to bees, including puddles.

III No bee precaution, except when required by the pesticide label or regulations.

STEP 3: GROWTH (CONTINUED)

Frost Risk

Frost risk in almonds is highest at petal fall, when temperatures below 30F° can damage young nuts,[17] but is a potential issue any time after dormancy through spring. Cover crops reduce soil surface temperatures compared to bare moist soil,[18] and thus can reduce the heat transfer from the orchard floor at night.

However, the surface temperature of an orchard with cover crops is higher than that of dry bare soil because water in the cover crops holds heat. From this perspective, a cover crop could decrease frost risk relative to bare soil.

Recent research from UC Davis shows that air temperature three-to-five feet above ground level is not reduced in cover cropped orchards compared to bare ground, indicating that in some cases the presence of a cover crop may not affect overnight temperatures at the canopy level, despite differences at the ground level.[19]

Founded on UCCE research, the current recommendation for managing cover crops and orchard vegetation in areas at risk of frost is to monitor weather patterns and low-mow cover crops (less than two inches) if there is a risk of overnight frost. In many cases, this will terminate the cover crop.

Some growers in especially frost-prone areas may choose to mow shortly before bud-break to limit risk of frost injury. In this precautionary scenario, species that tolerate mowing, including most grasses and some clovers such as berseem clover,[20] may be preferable because they can regrow later in the spring and provide soil coverage during heavy rain events that might otherwise impede orchard access. Alternatively, planting predominately low-growing clovers may decrease the urgency of mowing.

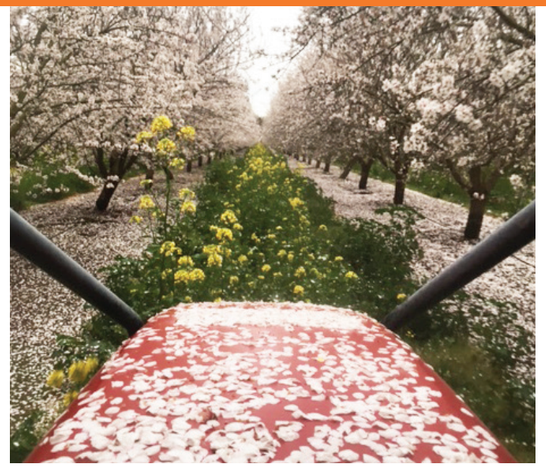
Mowing

High mowing can help control weeds, increase the overall biomass contribution of the cover crop (like a grazed forage crop) and contribute to overall diversity by providing light to species that may otherwise be outcompeted. This management strategy is common for many species[21] and can help prevent cover crop biomass from becoming woody and hard to manage.

Repeated mowing to keep cover crops manageable with additional orchard activities might have additional benefits for soil carbon sequestration. However, high mowing may limit the flowering potential of the cover crop, reducing bee forage. Typically, high mowing will be most effective in February or March, depending on cover crop maturity.

Partial or strip mowing is an opportunity to manage cover crop vegetation while promoting beneficial insect habitat. Strip mowing can be accomplished by mowing one side of a single orchard middle or mowing the entirety of alternate middles. In either scenario, biomass and potential interference with orchard management is reduced while some cover is left undisturbed, which provides habitat for beneficial insects throughout the orchard during cover crop growth.

In April, this clover cover crop was mowed to stand at 3-4 inches. The photo on the left shows the orchard immediately after mowing, and the photo on the right shows the clover regrowth after one week. Photo courtesy of Christine Gemperle



STEP 4: TERMINATION

Timing for termination will depend on the specific goals you hope to accomplish and the opportunities and constraints of your operation. The following table details some of the benefits and potential tradeoffs of different termination strategies.

TERMINATION TIMING	
BENEFITS	**TRADEOFFS**
Early Termination (February to mid-March)	
Start breaking down cover crop residue before other operations	Limited biomass accumulation
Mowing will destroy mummy nuts that are in the cover crop closer to normal shredding time	Winter rains may not have ended, so significant re-growth or resident vegetation may need to be managed later in the spring
Cover crop residue will have a low C:N ratio	May not flower before termination (legumes fix maximal nitrogen at 50% flowering)
Limits cover crop’s ability to increase frost risk	Limited time to provide forage for pollinators (for flowering species)
Appropriate termination timing for brassicas if they have reached peak (more than 90%) bloom	
Mid-Termination (mid-March to April)	
More biomass accrual (may still have low C:N ratio)	May not accrue full nitrogen benefits if cover crop has not bloomed (legumes fix maximal nitrogen at 50% flowering)
Terminate before fertigation to avoid nutrient uptake or competition from the cover crop	Limits quality of forage for wild insects
Facilitates other orchard operations like spraying	Fast-growing brassicas may be woody and difficult to manage
Late Termination (May to June)	
Some species, especially clovers, may have desiccated and will therefore break down more quickly	Less nitrogen benefits if cover crop is left growing well beyond flowering
May have time to set seed (could also be undesirable)	Biomass may be large and unruly
Ample time for flowering to provide pollinator forage	Some species, especially brassicas and grasses, may be woody and difficult to break down

This brassica cover crop, which flowers in April, has been seeded at a width that allows it to be terminated with a single pass of the flail mower. Photo credit Loren Thompson, courtesy of Project Apis m.

STEP 4: TERMINATION (CONTINUED)

Mowing

Mow to terminate the cover crop and again, as necessary to break down cover crop residue (for most growers, this will be three-to-five times between termination and harvest).

Cover crop biomass and age will affect how difficult it is to mow. The more biomass there is in the orchard middle, the slower the mower speed will need to be for proper maceration of the biomass to facilitate quick decomposition.

Most growers will use flail mowers or rotary mowers. Flail mowers contribute to faster biomass decomposition because they chop material more finely. Some growers may choose to terminate the cover crop using a roller crimper and then allow the residue to decompose on the soil surface. A roller crimper can negatively affect nut harvest but has the benefit of potentially suppressing summer weeds and helping maintain soil moisture during the summer.

Herbicides

Herbicides can be used for cover crop termination or after mowing to limit cover crop regrowth, but many growers report this is unnecessary. There are many resources available for growers to learn about alternatives. Growers who choose to use herbicides near harvest time must follow label instructions to minimize the risk of herbicide residues on the nuts. Orchard scouting will be necessary to choose an appropriate herbicide based on what cover crop and weed species are in a particular location. Consult a licensed pest control adviser for any chemical pesticide use.

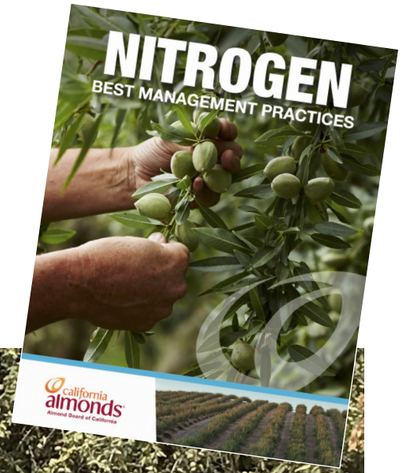
Most residual herbicides used in almond orchards are applied to strips centered along the tree row. Herbicide residues in the tree row are likely to inhibit cover crops from establishing; this may be a benefit for growers who are concerned about competition between the trees and the cover crop. If planted cover crops are part of your orchard middle management, carefully consider the residual activity of any herbicides used in this management zone.

Tillage

Some individuals use tillage to incorporate cover crops into the soil, while others let the residue decompose on the soil surface. Tillage in this case refers to mechanical disturbance of the soil that at least partially incorporates residue into the soil. Incorporation can be accomplished by a range of tillage equipment types which result in disturbance that ranges from minimal to severe.[22] Residue incorporation via tillage is beneficial for nematode suppression (see “Step 1: Planning”), to reduce nitrogen losses from volatilization,[23] and to speed decomposition and nitrogen release from biomass.[24] Tillage can also be used for weed control. However, excessive tillage can negatively impact soil structure[25] and the same microbial processes that drive decomposition reduce the opportunity for carbon accrual.[26] Some growers also find that tillage increases the amount of soil picked up with nuts at harvest.

Nitrogen Management

Cover crops that are managed for nitrogen contribution should be factored into a grower’s timeline of nitrogen dynamics over the growing season (see Figure 3 in ABC’s Nitrogen Best Management Practices).[27] Cover crop contributions to nitrogen budgets can be estimated from aboveground biomass and the growth stage of a given cover crop species.[28] Depending on termination and decomposition rate, leaf nitrogen measurements taken during the recommended April or July sample will allow growers to adjust fertigation or organic matter amendment requirements based on tree needs, which will include contributions from cover crops. Growers should monitor leaves and/or soil for nitrogen levels and adjust fertilization, as necessary.



In this Kern County orchard, the cover crop was terminated in mid-March, allowing for a clean orchard floor at harvest. Photo courtesy of Mohammad Yaghmour

STEP 5: POST-TERMINATION UNTIL HARVEST

Difficulty of almond harvest due to cover crop debris is the top concern among growers. However, **cover crops can be managed to decompose fully and disappear by harvest.** Specific timing will vary by farm, but the following are general suggestions:

- Terminate cover crops while they are still lush and vegetative to encourage rapid decomposition.
- Wet at least a portion of macerated cover crop residues (will happen during tree watering depending on irrigation) to help hasten decomposition.
- Mow multiple times after termination to break down residue. Many growers mow cover crops between March and May, and then mow multiple times afterwards, or mow and spray with herbicides in June or July to clear the orchard middles for harvest.

At harvest, growers can employ conditioners to speed up nut drying and limit the amount of cover crop and other debris transported to hullers. Conditioners require an extra pass through the orchard to provide these benefits but can eliminate the need for a completely clean orchard middle prior to harvest and facilitate accrual of benefits that come from keeping the soil covered.

ADDITIONAL COVER CROPPING STRATEGIES

The cover crop management practices described in this guide apply to the most common cover cropping strategies, but there are many options to achieve your goals and increase orchard biodiversity. Some additional options, described below, can offer growers more flexibility to meet orchard-specific goals and contribute to the long-term vitality of their orchard system. Many of the management guidelines outlined in this guide can also complement the strategies outlined below.

Resident Vegetation Management

"Cover crops" typically refers to planted annual vegetation chosen from a set of species that have been identified through research to have beneficial traits to accomplish particular goals. Unplanted vegetation that grows from the seedbank in the soil is also called resident vegetation or "native vegetation," though it is not necessarily composed of species native to the area, and may include desirable or undesirable species.

Planted cover crops and resident vegetation offer some of the same benefits within the almond orchard system, but they differ in key ways, as shown in the following table.

COVER CROPS	RESIDENT VEGETATION
More predictable vegetation	Less predictable vegetation
Seed costs	No seed costs
More management labor (seeding, mowing)	Less management labor (mowing only)
More possibility for even soil coverage	Less control over coverage
Possible targeted root benefits (ex: taprooted species)	Possible herbicide resistant species
Possible additional nitrogen benefits (legumes)	Possible noxious species (ex: field bindweed)
Possible improved floral resources (brassicas, legumes, flowers)	Possible greater biodiversity

Choosing to use a cover crop or to manage resident vegetation will depend on your orchard characteristics, as well as the species composition of the resident vegetation. Managing orchard middle vegetation, whether planted or unplanted, requires many growers to reconsider the concept of what a "clean" orchard is. This may include recognizing which resident species you can tolerate and even promote in your orchard, or which cover crop species you can plant, and recognizing the tradeoffs between vegetated orchard middles and orchards maintained to be vegetation-free via cultivation or herbicides.

Annual Cover Crops Managed to Set Seed

Cover crops in almond orchards are not typically managed for reseeding potential because doing so requires delaying mowing until after seed production (often in May or June), which, depending on the species, can lead to tough or woody cover crop residues that interfere with harvest. Additionally, naturally reseeded cover crops will become less diverse and may narrow the benefits compared to a more diverse mix in subsequent years.

Greater natural reseeding success can be achieved with some clover species and annual native flowering plants. Growers with microsprinkler irrigation systems will likely have more success with natural reseeding as irrigation can help break down mature cover crop biomass prior to almond harvest. Some growers have found that after planting cover crops in young orchards, which have not yet been harvested, enough biomass will grow in the middles that annual cover crop seeding is not necessary. This strategy limits control over the type of vegetation growing in the middles but may accomplish your goals for a cover crop without additional seed expenses.

A legume cover crop planted after winter sanitation, in January or February, will confer few benefits in the first year, but has low potential to become woody, and therefore could be allowed to go to seed. The following year it would provide cover and insect forage and could be maintained and augmented like a perennial cover crop in future years.

Perennial Cover Crops

Perennial cover crops, such as white clover (Trifolium repens), are uncommon in almond systems. There is no research on the impact of harvest ease with a perennial groundcover, though growers have mentioned that in drip-irrigated systems a spring-mown clover will mostly disappear during the summer, thus not affecting nut drying and pick up. Perennial cover crops would be seeded and managed following the same principles as annual cover crops, but without annual reseeding.

Growers who are interested in perennial ground cover may want to try it on a very small scale to start, or on a hedgerow, to see how much breakdown actually occurs before experiencing it at scale. It is also important to note that perennial clover may attract gophers and can be difficult to manage with herbicides once established.[29]

Alfalfa is one perennial cover crop that growers may seek to experiment with in or near their orchards.

Cover Crops and Livestock Integration

Integrating livestock (small ruminants or chickens) into almond orchards can be used as a mowing or termination strategy, or as part of an agroforestry rotation. For small ruminants, sheep are preferred over goats because sheep tend to focus on the ground and limit damage to trees. Livestock can be introduced to the orchard at any time when the cover crop is large enough to provide forage, typically in February through April.

Livestock integration is not recommended by the Almond Board of California due to food safety concerns. To comply with food safety requirements, animals must be removed from the orchard more than 90 days before harvest if the almonds are harvested off-ground, and more than 120 days before harvest for almonds that are shaken to the ground.[30]

For additional information on cover crops, view the Additional Resources listed below and visit the Almond Board of California website:

Almonds.com/CoverCrops

As you consider planting cover crops, don't forget these three steps:

1. **Plan ahead and start small,**
2. **scale up using available resources, adjusted practices when needed, and**
3. **find fellow growers, advisers, and/or researchers with whom to compare results and brainstorm innovations.**

A brassica cover crop can be managed to bloom at the same time as the almond trees.

ADDITIONAL RESOURCES

FUNDING SOURCES

CDFA Healthy Soils Incentive Program

Provides funding for growers to implement conservation management practices that sequester carbon, reduce atmospheric greenhouse gases and improve soil health.

More information: www.cdfa.ca.gov/oefi/healthysoils/incentivesprogram.html

NRCS Environmental Quality Incentives Program

Provides funding for growers to conduct on-farm practices that improve environmental quality, including cover crops. For more information, see their website and contact the NRCS Field office in your county.

More information: www.nrcs.usda.gov/wps/portal/nrcs/main/ca/programs/financial/eqip/

NRCS Field Office Locator: offices.sc.egov.usda.gov/locator/

Project Apis m. Seeds for Bees Program

Project Apis m. is committed to increasing honey pollinator-friendly habitat and cover crops in almond and other California orchards.

More information: www.projectapism.org/

Seeds for Bees program overview: www.projectapism.org/seeds-for-bees.html

Seeds for Bees seed mixes: www.projectapism.org/pam-seed-mixes.html

Growers guide to benefits, water use, bloom competition, and FAQ's:
www.projectapism.org/seeds-for-bees-for-the-grower.html

ADDITIONAL RESOURCES (CONTINUED)

INFORMATIONAL RESOURCES

University of California Division of Agriculture and Natural Resources

- **Year-Round Integrated Pest Management Program for Almonds:** www2.ipm.ucanr.edu/agriculture/almond/
- **Sacramento Valley Orchard Source – Cover Crop Seed Selection Summary:**
  www.sacvalleyorchards.com/almonds/horticulture/cover-crop-seed-selection/
- **Cover Crop Selection Tool** cekern.ucanr.edu/CDFA_Grants/HSP_Grants/Cover_Crop_Selection_Tool/
- **Winter Cover Crop Cost-Benefit Calculator for Almonds:** shiny.lawr.ucdavis.edu/shiny/cc_calculator/app.Rmd

UC ANR Resources list:

- **Growing the Valley Podcast:** growingthevalleypodcast.com

Natural Resources Conservation Service

The NRCS is a leading source of information about managing soil and cover crops. A few of their California-specific publications about cover crops are provided below, and more information can be found on their website: nrcs.usda.gov

- **Vegetation ("EVeg") Guide for Choosing Cover Crop Species:** www.calflora.org/nrcs/
- **Cover Crop Chart – Common Cover Crops for California:**
  www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/capmctn13333.pdf

Water Management

- **California Irrigation Management Information Systems (CIMIS) Online Spatial Evapotranspiration Data for California, managed by the California Department of Water Resources and UC Davis:** cimis.water.ca.gov

Xerces Society for Invertebrate Conservation

The Xerces Society provides many resources to help growers select, plant and monitor native and non-native vegetation for the benefit of bees, butterflies, and other beneficial insects. In addition to their publications listed below, which may be of particular interest to almond growers, the society offers many more resources on their website: xerces.org.

- **Bee Better Certified: A Farmer's Guide:** www.xerces.org/publications/brochures/bee-better-certified-farmers-guide
- **Recommended Cover Crops and Plants for Pollinators and Natural Enemies in the California Central Valley:**
  www.xerces.org/publications/plant-lists/ppbi-california-central-valley
- **Natural Enemies Scouting Guide:** www.xerces.org/publications/scouting-guides/beneficial-insect-scouting-guide

American Farmland Trust

American Farmland Trust has worked with California almond growers to quantify the economic and soil health impacts of adopting a suite of soil health practices, including cover crops. Read the published case studies, linked below, to hear from farmers who have successfully adopted these practices. If you have achieved successful soil health and would like to know what the economic impacts of your soil health practices are, you are invited to use the Retrospective Economic Calculator. The Economic Calculator may also be of interest to UCCE farm advisers and other allied industry members who work with growers.

- **Case Studies:** farmlandinfo.org/publications/soil-health-case-studies/
- **Retrospective Economic Calculator:** farmland.salsalabs.org/sh_casestudies_methods/index.html

Community Alliance with Family Farmers

The Community Alliance with Family Farmers has worked with California farmers for decades to create sustained food and farming systems. In the almond industry, the alliance is well-known for its collaboration with UCCE in the Biologically Integrated Orchard Systems (BIOS) program. In addition to the resources below, more information is available on their website: caff.org.

- **BIOS for Almonds Guide:** www.caff.org/biologically-integrated-orchard-systems-bios-for-almonds-guide/
- **Hedgerow & Farmscaping Guide:** www.caff.org/hedgerows-farmscaping-for-california-agriculture-guide/
- **Cover Crop Decision Guide for Perennial Systems:** www.caff.org/cover-crop-decision-guides/

Pollinator Partnership

Pollinator Partnership seeks to engage growers of a wide range of crops nationwide in promoting pollinator health on their operations through the Bee Friendly Farming program. Under the program, growers who meet specific criteria are eligible to be certified as "bee friendly" and be recognized publicly for their commitment to pollinator health.

Growers interested to learn more about the Bee Friendly Farming program should visit www.pollinator.org/bff.

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