Cover Cropping for Pollinators and Beneficial Insects



Doug Crabtree uses many tools to make his Montana farm bee friendly. – *Photo by Jennifer Hopwood;* **Phacelia is an attractive pollinator cover crop.** – *Photo by John Hayden;* **Clover fixes nitrogen and provides bee forage.** – *Photo by Judson Reid*

DOUG AND ANNA CRABTREE'S VILICUS FARM RESTS on more than 2,000 acres in northern Montana, and it is a model of how cover crops can be a foundation of pollinator and beneficial insect management. Like many farmers, their approach to cover cropping began with an interest in soil health and quickly grew to encompass much broader goals as they recognized the additional benefits cover crops could provide.

"We want to implement pollinator conservation at the field-level scale," Doug says. "Anyone can create a small wildflower strip, but as we scale up, we need conservation areas distributed across the entire operation."

While the Crabtrees have established permanent native wildflower strips around many of their fields to provide a skeleton of habitat throughout the farm, extensive cover crop rotations provide the muscle that makes their operation a rich landscape for bees and other beneficial insects.

This commitment to cover cropping is having clear and positive impacts. Flax, sunflower and safflower are just a few of the Crabtrees' regular crops that either require or strongly benefit from insect pollination. And, because of their commitment to integrating habitat for wild pollinators throughout their holdings, the Crabtrees have never needed to bring honey bee hives onto the farm for pollination. Instead, a walk through their fields quickly reveals an abundance of wild bumble bees, longhorn bees, sweat bees and more—all supported by the farm's habitat. A farm's ability to support its own pollinator community provides security, especially if managed honey bee hives become scarce or expensive.

In addition to supporting the pollinator community, cover crops have many traditional uses on a farm. These range from preventing erosion and improving soil health to managing weeds and serving as an additional source of income when part of a double-crop system. With cover

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crops planted on more than 15 million acres annually, many farmers already appreciate the role diverse agroecosystems play in improving profitability. Cover crops will often pay for themselves within a few years of use, according to a SARE report on cover crop economics [1a] that was based on a five-year survey of farmers conducted by North Central Region SARE and the Conservation Technology Information Center (CTIC) [1b]. While the CTIC-SARE survey revealed that 38 percent of cover crop users already choose plants in order to support pollinators [1b], cover crops reap many additional benefits.

Flowering cover crops can fulfill their original purpose as a conservation practice while at the same time providing valuable forage for wild bees and beneficial insects. This added benefit can be significantly enhanced with some fine-tuning of management practices and thoughtful plant selection.

This bulletin will help you use cover crops to encourage populations of pollinators and beneficial insects on your farm while you address your other resource concerns. It begins with a broad overview of pollinator and beneficial insect ecology, then describes cover crop selection and management, how to make cover crops work on your farm, and helpful and proven crop rotations. It will also touch on the limitations of cover crops and pesticide harm reduction, among other topics.

Cover crop mixes can offer multiple benefits. This mix of sunn hemp and radishes in South Dakota provides livestock grazing, pollinator forage and brooding cover for pheasants.
– Photo by Ben Lardy, USDA NRCS in cooperation with Pheasants Forever Inc.

Basic Pollinator Ecology

WHILE MANY INSECT GROUPS ARE POLLINATORS, BEES are the most important because they actively seek pollen to feed their young. In addition to the domesticated European honey bee, roughly 3,600 species of wild bees can be found in the United States and Canada. Among these, honey bees and bumble bees are social animals, living in complex family units with a single queen, female workers (the daughters of the queen) and a few male bees called drones. In contrast, most wild bees (except for bumble bees) are solitary animals, with each female locating and provisioning her own nest.

Honey bees and wild bees alike are considered important agricultural pollinators, and both groups of bees share many of the same habitat requirements necessary to thrive. Both require reliable and abundant pollen and nectar resources throughout the growing season. In the case of honey bees, nectar demands can be significant, requiring large-scale flowering habitats to produce surplus honey.

In addition to the availability of food, honey bees and wild bees require protection from pesticides. While large doses of pesticides may be directly lethal to bees, smaller doses can result in sublethal impacts, such as reduced reproduction or foraging. Interestingly, research suggests that diverse pollen and nectar resources may help improve the overall health of bees and increase their chances of detoxifying low doses of some pesticides.

Along with food availability and pesticide protection, wild bees have a third habitat requirement: undisturbed areas for nesting. Many wild bee species prefer undisturbed soils. These soil-nesting wild bees excavate underground tunnels and provision them with pollen clumps, onto which they lay their eggs. Other wild bee species nest in the hollow stems of plants, including the stems of some trees, shrubs, large grasses and even large wildflowers. A few species, including bumble bees, typically nest in the abandoned underground burrows of small rodents, or in other similar cavities.

With appropriate plant selection and proper management, flowering cover crops can support the habitat requirements of bees through pollen and nectar resources to maximize their health and reproductive potential, an abundance of nectar to produce surplus honey, a refuge from insecticides, and sometimes enhanced nesting opportunities for wild bee species.

Other Beneficial Insects

THE NATURAL ENEMIES OF CROP PESTS THAT SOMETIMES inhabit farms include a diverse range of predatory beetles, aphid-eating flower flies, lacewings, small solitary parasitic wasps and many others. In addition to preying upon crop pests, most of these predatory and parasitoid insects either need or benefit from alternative food sources during at least one stage of their life. In some cases that means nectar or pollen. Consequently, like pollinators, many of these natural pest enemies also benefit from flowering cover crops.

A SARE-funded group of University of California researchers demonstrated that mixed species of flowering cover crops in vineyards increased beneficial insect populations [2]. The increase in beneficial insects, brought about by a mix of annual buckwheat, lacy phacelia, sweet alyssum, bishops weed and wild carrot, resulted in fewer pests, such as the vine mealy bug.

In other cases, cover crops can support beneficial insect populations even when they do not flower. Some predators and parasitoids do not feed on nectar and pollen, but rather need a continuous supply of prey insects to maintain their local populations at an effective level. So when cash crops are absent, non-flowering cover crops can support pests to the extent that they become a stable food source for beneficial insects. For example, ground beetles, which are generalist predators of slugs, caterpillars and grasshopper eggs, can be sustained by leaving some areas unmowed or by creating a "beetle bank" of perennial grasses outside crop fields. Beetles can overwinter in this augmented habitat and their prey can breed in it. Thus, these grassy refuges can keep the beetle population high by providing both habitat and a food source outside the cropping period.

Similarly, even if prey insects found in cover crops are not pests of your cash crops, they can still be an important food resource for predator and parasitoid insects that will switch their prey preference once cash crop pests become available.

Finally, like pollinators, predatory beneficial insects need protection from insecticide applications and vegetative structures for egg-laying or overwintering. Well-managed cover crop systems can help meet these habitat requirements.

PERENNIAL COVER FOR ORCHARDS AND VINEYARDS

FAST-GROWING ANNUAL COVER CROP SPECIES SUCH AS RYE AND CRIMSON CLOVER ARE the most common choice for rotation with annual field crops. However, in perennial farm systems such as orchards and vineyards, longer-term ground cover may be desired. In these settings, the ground cover may have multiple demands placed upon it, including erosion control, nutrient management, and pest and disease suppression. As long as these perennial ground covers are combined with a thoughtful and careful approach to pesticide use, pollinator conservation can be very compatible with other goals.

For example, perennial turf grass in orchards can be enhanced for pollinators simply by tolerating non-invasive weeds such as violets or dandelions. To go a step further and actively increase pollen and nectar resources, such perennial turf grass systems can be over-seeded with various low-growing perennial clovers. Where these approaches are used, it is critical that insecticides not be over-sprayed and allowed to drift down onto flowering plants in the ground cover. Some farmers with these types of ground covers simply mow them to remove flowers before spraying. Although a mowed ground cover without flowers may significantly reduce the landscape value for pollinators, it is preferable to killing bees that might otherwise move on to areas where no spraying is taking place.

For maximum value to pollinators and other beneficial insects, native annuals and perennials can be added to the cover crop understory of orchards and vineyards. These systems typically provide maximum benefits to native pollinators and other beneficial insects. They are also well adapted to the local climate, more resistant to local diseases and pests, and do not require routine mowing or irrigation.

Cover Crops On Your Farm

BEYOND SUPPORTING BEE AND BENEFICIAL INSECT populations, cover crops can reduce your costs for herbicide, insecticide and fertilizer, and improve overall soil health and profitability [1a, 3]. Many cover crops can be included in a double-crop system or used as animal forage. Cover crops can be integrated into most crop or crop-livestock systems, including no-till, conventional till, rotational no-till and livestock grazing or haying systems. In the CTIC-SARE survey, farmers who plant cover crops identified these top five reasons for doing so (in order): increase soil organic matter, reduce soil erosion, reduce soil compaction, manage weeds and provide a nitrogen source [1b].

The economic benefits associated with cover crops can be both significant and realized in year one, depending on how and why they are used [1a]. On a Georgia cotton farm, a grower reduced costs by $200 per acre by implementing conservation tillage and cover cropping. His cover crop cocktail combined crimson clover, an excellent nectar plant and nitrogen source; and rye, a soil-

Strips of flowering cover crops such as lacy phacelia and sweet alyssum (pictured) can manage vineyard pests such as the vine mealy bug by supporting beneficial insects.
– Photo by Miguel Altieri

Cotton growing in a system using cover crops and conservation tillage. A cover crop mix of rye and crimson clover can improve the profitability of cotton because the clover adds nitrogen to the soil and the rye attracts beneficial insects.
– Photo by Stephen Kirkpatrick, USDA NRCS

builder and nitrogen scavenger. Between the savings on fertilizer from the clover's nitrogen enrichment and reduced insecticide costs thanks to beneficial insect activity, this farmer observed that many pests were no longer a problem in his fields [3]. Similarly, a Pennsylvania vegetable farmer cut pesticide costs by 40 percent (saving $125 per acre) by using a combination of cover crops [4], and a North Dakota farmer saw net profits on his barley harvest increase by $109 per acre on cover cropped fields. He was also able to harvest his cover crops as forage for his cattle [5].

There are many tools available to farmers as they weigh the economics of adding cover crops to their system (see Resources). *Cover Crop Economics*, a SARE report based on national survey data of cover crop use, describes seven management situations when cover crops can quickly pay for themselves in corn/soybean systems (one to three years) [1a]. These include when herbicide-resistant weeds are a problem, when cover crops are grazed, when soil compaction is an issue, when transitioning to no-till, when fertilizer costs are high or manure nutrients need to be sequestered, when soil moisture is at a deficit or irrigation is needed, and when incentive payments are received.

While a 2005 survey in the Corn Belt found that more than half of all farmers said they would use cover crops if they received cost-share funds [7], the more recent CTIC-SARE survey found that farmers are increasingly likely to try cover crops without any sort of financial assistance. This survey found that 63 percent of farmers said they had never received cost-share funds, and only 8 percent restricted their cover cropping to times when they received funding [1b]. Although cost-share programs improve the profitability of cover crops, many farmers who use them—perhaps the majority—look beyond the balance sheet when assessing their value. It seems that financial assistance can open the door to cover cropping, but many farmers with experience cover cropping do not require it [1b]. The less easily quantified conservation benefits of cover crops, such as their role in soil health and pollinator promotion, are the important consideration for many.

Opportunities to Use Cover Crops

ONE OF THE FIRST STEPS WHEN INCORPORATING COVER crops in your system is identifying available niches. You may already have periods in your cropping systems which are open to cover crops. Common niches for cover crops include during the winter fallow, during a summer fallow between cash crops, during a small-grain rotation or during a full year of improved fallow [3]. Cover crops are often used in a corn/soybean rotation, with specialty crops or following small grains [1b].

Cover crops sown after the cash crop in the winter fallow niche serve multiple purposes. They both prevent soil erosion and—if they are nitrogen scavengers—can prevent nutrient leaching [3]. Available cover crop niches will vary with the local climate and the cash crops in your rotation. For example, in Minnesota, many growers plant cover crops after corn harvest in September for winter cover [8]. Meanwhile, in North and South Carolina, cover crops are often used to absorb excess nutrients after manure applications [9].

John and Nancy Hayden grow 30 varieties of tree fruit and berries at The Farm Between in Jeffersonville, Vt., and maintain a pollinator sanctuary of perennials, trees and brush piles on their property. Even with such an abundance of flowering plants and habitat, they identified a need for summer cover crops. "We notice in July and August here in the Northeast there's a dearth of floral resources," John says. "So for us, it was seeing if we can fill a gap that we can't with our perennials using annual cover crops."

The next step in getting the most out of your cover crop is to identify your conservation needs. You may need to break up a plow pan (daikon radish), prevent nutrient leaching (non-legumes, cereals), boost soil fertility with a green manure (legumes), out-compete weeds with a fast-growing plant (buckwheat), provide forage for livestock (crimson clover, canola, cereals), manage nematodes (brassicas), or prevent erosion (cowpea, clovers). Increasingly, farmers are turning to cover crops in "prevented planting" situations—that is, when the soil is too wet to plant in the spring [1b].

The Haydens used a 2013 SARE grant to evaluate three cover crop options—phacelia, buckwheat and a commercial bee forage mix—for their ability to support bumble bees and suppress weeds in vegetable beds where weed pressure had built up [10]. The phacelia and buckwheat established well, suppressed weeds and attracted pollinators, but the commercial mix was outcompeted by weeds and did not establish well. "The phacelia we liked a lot," John says. "We were able to see that bumble bees had a statistically significant preference for phacelia over buckwheat."

Ideally, your cover crop will be dual-purpose. It should both serve as a conservation practice and also boost beneficial insect populations. Your cover crop mixture must include flowering legumes or forbs to accomplish this objective. See Plant Selection for an in-depth discussion of choosing plants for multiple objectives.

As a cover crop, fast-growing buckwheat is commonly used to suppress weeds. When allowed to flower, it can provide excellent forage for wild pollinators.
– Photo by John Hayden

Planting and Managing Your Cover Crops

COVER CROPS CAN EITHER BE SOWN AFTER HARVEST OF a cash crop, or they can be sown into a standing crop (over-seeding). Typically, drilling uses fewer seeds than broadcast seeding and promotes more uniform stand establishment. It can be done post-harvest or into a standing crop, and is the technique most commonly used by farmers in the CTIC-SARE survey [1b]. Other farmers aerially over-seed cover crops into a standing crop. Over-seeding is most commonly used to give cover crops a head start before the winter in regions with a short growing season. The CTIC-SARE survey found that the median seed cost in the Midwest was $25 per acre in 2013 [1b].

As you decide when to terminate your cover crop, the goal is to give time for cover crops to decompose, release nutrients and recharge soil moisture, and to avoid competition with the cash crop [11, 12]. You need to weigh these demands against the need to minimize the amount of time your fields are bare. Appropriate termination time for cover crops varies by region.

At the time of this writing, federal crop insurance programs have developed region-specific requirements for cover crop termination. These rules are intended to reduce yield losses of cash crops due to water use by previously planted cover crops. They require the termination of cover crops in advance of cash crop planting, from at least 35 days before planting to up to five days after planting, depending on the region. For more information, see Balancing Insect Conservation with USDA Crop Insurance Rules on page 9.

If pollinators are to benefit from your cover crop, you must give it time to flower. This is not a problem with legumes or brassicas. Their conservation benefits are maximized after they bloom. Management of some other plantings can be a little trickier, such as buckwheat. Buckwheat must flower for a minimum of 20 days to build up beneficial insect populations [3]. At the same time, buckwheat should be mowed seven to 10 days after flowering to prevent it from reseeding [3]. Because buckwheat is one of the best cover crops for bees and beneficial insects, and it kills so easily with mowing, it may be advisable to put off cover crop termination until beneficial insects are established, with the expectation of having to mow a field twice to achieve cover crop termination. Note, however, this practice could result in unwanted buckwheat becoming a weed. Alternatively, a farmer could stagger planting and mowing row by row to lengthen the bloom period while still preventing buckwheat from reseeding.

When the Haydens used buckwheat as a summer cover crop, they allowed it to flower extensively and go to seed, and did not follow it with a fall crop. With unfavorable conditions for germinating through the fall and winter, volunteer buckwheat was not a problem come spring. "From our experience, reseeding would only be a problem if you were planting another crop the same season," John Hayden says. "Neither phacelia nor buckwheat presented any problems with volunteers the year after planting."

Another cover crop practice that may require some additional tweaking to benefit bees and beneficial insects is planting for green manure. Green manure is tilled into the soil to increase soil organic matter in the vegetative stage or at flowering. This practice can be made more insect-friendly by allowing the green manure crop to flower for a few extra days, but still tilling before seed set.

Cover crops can be terminated by mowing, tillage, herbicides, harvesting, rolling or winter kill. An herbicide burn down is the most common termination strategy, followed by tillage and winter kill [1b]. Roller-crimpers avoid both chemical inputs and tillage. You may also opt to graze or hay your cover crop for winter forage. The best option will vary depending on plant selection and growth stage. Deep tillage should be avoided, as it tends to counteract many of the benefits provided by cover crops. These range from improved soil tilth to increased populations of over-wintering beneficial insects.

Plant Selection

THE PLANTS THAT BEST FIT YOUR NEEDS WILL VARY BY location and purpose. Different cover crops have different strengths. Flowering broadleaf species are a must when selecting cover crops for pollinators. Grass cover crops do not provide nectar and their pollen typically has lower protein content than the pollen of broadleaf plants, thus making them only marginally attractive to bees. A flowering plant/grass blend may be an ideal solution in situations where a grass crop is needed to achieve other management priorities, such as preventing nutrient leaching.

You have more flexibility when selecting plants in support of predator and parasitoid insects for pest management, with certain grass cover crops supporting alternate prey (such as aphids) to help sustain the beneficial insects when cash crops are absent.

Cover Crop Services and Examples of Suitable Pollinator-Friendly Plants [1, 13]

Conservation Service	Pollinator-Friendly Cover Crops
Nitrogen source	alfalfa, white clover, red clover, cowpea, lupin, partridge pea, sunn hemp, vetch
Nitrogen scavenger	phacelia, canola, sunflower
Erosion control	canola, cowpea, crimson clover, white clover
Forage value	crimson clover, canola, white clover, forage radish
Weed management	buckwheat, canola, cowpea, sunn hemp, sunflower
Nematode management	canola, other brassicas and mustards
Reducing compaction	canola, radish, lupines, brassicas and mustards

Avoid cover crops that serve as alternate host plants for crop diseases and those that support large numbers of crop pests. An alternate host is another species, different from the cash crop, which serves as a reservoir for the pest or is necessary for the pest to complete its life cycle. For example, if you are growing a brassica vegetable crop, do not cover crop with another brassica, as it would support similar pests.

However, cover crops that support low levels of crop pests may be valuable in some cases, as they can provide a consistent food source for beneficial predators. This is well documented in the case of pecan orchards with a clover understory [14]. The legumes attract aphids, which are followed by beneficial insects. When the clover dies back and the aphid population drops, the beneficial insects are driven up into the trees. These insects, in search of other foods, manage pests on the developing pecans [14].

Be sure the cover crop you choose is adapted to local conditions. A good first step is to talk with local farmers who use cover crops and conservation specialists. Red clover and crimson clover are popular cover crops for nitrogen fixation east of the Mississippi River [3]. Red clover is a low-bloat legume that is excellent forage for grazing animals. Clover is also a high-value honey plant. Rapeseed and other brassicas are used for pest and nematode management in fields (biofumigation). Cowpeas, another legume, are exceptionally heat and drought tolerant. They also have extra-floral nectaries—or nectar-producing glands at leaf stems—which attract beneficial insects. These plants are used for erosion control across the Southeast and coastal California [3]. They are also used for weed suppression in the Deep South. Buckwheat is useful as a rapid-growing smother crop in much of the United States [3], and it is the premier cover crop for attracting beneficial insects.

Of course, buckwheat is not ideal for every situation. Hoping to use buckwheat as a nectar source for predators of the glassy-winged leafhopper, a vineyard pest [15], SARE-funded University of California-Riverside Extension specialists found that the plant struggled to grow during the hot, dry southern California summer. Sustaining the cover crop with irrigation turned out to be an expensive proposition, and actually increased populations of the blue-green sharpshooter, another local vineyard pest. Ultimately the buckwheat did in fact increase predator numbers to help manage glassy-winged leafhoppers, but that benefit became more difficult to justify when balanced against unexpected challenges.

Finally, when considering plants, a strong case can be made for the role of diversity. Using a SARE grant, a graduate student researcher in Florida [16] found significant differences in wild bee abundance and diversity based upon the number of crops present on a farm. At one end of the spectrum, the farm with the fewest number of bees (five species) grew only two crops and mowed directly up to the field edges. The farm with the greatest abundance of bees (14 species) grew nine crop species and maintained open, unmowed buffer areas around the farm. Interestingly, both farms were relatively similar in size. While not explicitly demonstrated in the study, it seems likely that multi-species cover crop mixes are a relatively simple way to expand plant diversity on a farm, with probable benefits to bee abundance and diversity.

Cover Crop Cocktails

MIXTURES OF COVER CROPS, OR COCKTAILS, HAVE synergy—they generally work better than each single species could alone. In fact, a planting of legumes and grasses can result in an overall increase in available nitrogen [17]. Legumes build up soil nitrogen quickly, but their residue also decomposes quickly, releasing nutrients. A small grain does not add soil nitrogen, but it is an excellent nutrient scavenger. Additionally, its residue decays over a longer period of time, providing a slow-release mechanism for soil nutrients. Small grains are also useful for controlling erosion, preventing nutrient leaching and suppressing winter weeds. Mixing the fertilizing effects of the flowering legume with the soil-building small grain can be a winning combination for winter cover [1, 18].

A pollinator-oriented cocktail may include a mix of plants that have different strengths and which flower at different times. Buckwheat, rapeseed, lupines, phacelia, sunn hemp, cowpeas, partridge pea, sunflowers and many clovers are all cover crops that are also beloved by bees and beneficial insects. Stacking these pollinator plants in one field can lengthen the bloom period. For example, if rapeseed blooms in early spring and is harvested in May or June, then it can be followed by the late-summer blooming sunflower, which can then be over-seeded with a winter legume/small grain mix. The rapeseed serves to manage nematodes, the sunflowers mine nutrients and bring them to the surface, while the legume/grain mix adds nitrogen and prevents winter erosion. This is just one path using an all-pollinator rotation for season-long flowers. All of these plants except the small grain have flowers highly preferred by pollinators and other beneficial insects.

Common and Suggested Rotations

THERE ARE A NUMBER OF ROTATIONS THAT WORK WELL with common crops, and there is likely to be a proven cover crop rotation that works with your system. The NRCS *Cover Crop Economics Decision Support Tool*, released in 2014, comes pre-loaded with example scenarios to help farmers think about the economics of including cover crops in their system. For example, in a three-year corn/soybean/corn rotation with fall cover crops every year, including a winter cover crop of cereal rye following corn and a cocktail of cereal rye/crimson clover/brassica following soybeans had long-term benefits in terms of fertilizer and pesticide savings, with no reduced yield [6]. In another scenario,



Photos, from left to right: **Teff grain, phacelia and a fava bean flower**

COVER CROP COCKTAIL EXAMPLES

The following examples represent cover crop cocktails for various regions and seasons. They include pollen and nectar-rich plant species that support a diversity of bees and other beneficial insects, as well as vegetative structure that insects may use for egg laying or hibernation. Flowering will vary depending on season, planting date and region; these mixes can provide multiple benefits even when terminated before all species have flowered.

Sample Cool Season Cocktail (formulated for one acre at 10-15 seeds per sq. ft.)

Species	Percent of Mix	Quantity (pounds per acre)
Phacelia	8	0.2
Crimson clover	8	0.3
Radish (daikon)	8	0.6
Hairy vetch	8	2.2
Field pea	8	17
Turnip	8	0.2
Fava bean	2	29
Rye	25	6
Oat	25	7
Totals	**100 percent**	**62 pounds per acre**

Sample Warm Season Cocktail (formulated for one acre at 15-20 seeds per sq. ft.)

Species	Percent of Mix	Quantity (pounds per acre)
Buckwheat	16	7
Soybean	16	34
Sunflower	16	3.5
Cowpea	16	28
Sudangrass	12	2.5
Millet	12	1.5
Teff	12	0.1
Totals	**100 percent**	**77 pounds per acre**

Sample Tropical Cocktail (formulated for one acre at 15-20 seeds per sq. ft.)

Species	Percent of Mix	Quantity (pounds per acre)
Buckwheat	12	7
Sunn hemp	12	7
Sunflower	12	3.5
Cowpea	12	26
Yellow sweet clover	12	0.5
Teff	12	0.1
Sudangrass	14	3.5
Millet	14	2.5
Totals	**100 percent**	**50 pounds per acre**

NATIVE AND NEARLY NATIVE COVER CROP MIXES

EXTENSIVE RESEARCH DEMONSTRATES THAT NATIVE PLANTS FOSTER MORE abundant and diverse pollinator populations than non-native plant species. Similarly, other benefits of native plants, such as their adaptation to local climate conditions, are well understood. However, the vast majority of cover crop options consist of non-native plants. There are some exceptions, described below.

Phacelia (*Phacelia tanacetifolia*), a vigorous-growing annual native to California, and common sunflower (*Helianthus annuus*, pictured), a native of western prairie and desert states, are two species that continue to be more common in cover crop applications. Both are also extremely attractive to honey bees and a variety of native bees. While phacelia (first used as a cover crop in Europe) is sometimes planted as a single-species cover crop, both it and sunflower are increasingly used as part of diverse cover crop cocktails. While those cocktails still do not resemble true native plant communities, the inclusion of these plants within their native range may provide special benefits to local pollinator species.

More work is needed to identify and increase the availability of promising native plant species. Across eastern, southern and Midwestern states, for example, partridge pea (*Chameacrista fasciculata*), a native annual prairie legume, shows particular promise. In addition to its ability to fix nitrogen, partridge pea attracts large numbers of pollinators and beneficial insects with both flowers and extra-floral nectaries (nectar-producing glands located at leaf stems). The abundant biomass production and relatively low-cost commercial availability also make partridge pea an attractive native cover crop choice for warm-season applications.

While additional research is needed, farmers looking to experiment with local native plants as cover crops might seek out readily available, low-cost wildflower species and begin including them in cocktail seed mixes at a low rate. Annual species such as California poppy (*Eschscholzia californica*), blackeyed Susan (*Rudbeckia hirta*), lanceleaf tickseed (*Coreopsis lanceolata*), Douglas meadowfoam (*Limnanthes douglasii*) and plains coreopsis (*Coreopsis tinctoria*) may soon take their place alongside crimson clover and buckwheat in creating diverse cover crop seed mixes that blur the lines between agriculture and ecology.

SPECIAL CONCERNS: TERMINATION AND RESIDUE MANAGEMENT FOR GOOD BUGS

WHILE NECESSARY TO PREPARE FOR CASH CROP planting, the process of terminating a cover crop can be very detrimental to pollinators and beneficial insects, especially when the cover crop is actively flowering when terminated. The risks to insects from cover crop termination include direct mortality, such as being crushed by cultivation or roller-crimping equipment; and indirect harm, such as the rapid loss of available food sources. Even when adult insects are not present and active in cover crops, nest sites, eggs and hibernating adults may all be present in the crop canopy or upper soil surfaces.

Adopting cover crops for pollinators takes careful planning and consideration. To reduce some of the impact of cover crop termination, we recommend the following:

- Where possible, wait until most of the cover crop is past peak bloom before termination.
- If waiting until peak bloom is not possible, consider leaving strips of the cover crop standing to prevent the crash of beneficial insect populations. With buckwheat, for example, stagger planting and mowing row by row (or groups of rows) to lengthen the bloom period while still preventing buckwheat from reseeding.
- Terminate with as little physical disturbance as possible. For example, roller-crimping may be less disruptive to pollinator nests in the soil than cultivation.
- Maintain permanent conservation areas on the farm to sustain beneficial insects in the absence of the cover crop.
- Leave as much cover crop residue as possible to protect beneficial insect eggs and any hibernating adults.
- Minimize insecticide use in the cash crops that follow cover crops to avoid harm to beneficial insects that may still be nesting in crop residue. At a minimum you should follow a comprehensive integrated pest management (IPM) plan that includes specific risk mitigation strategies that protect pollinators and beneficial insects.

Including native flowering species in a cover crop mix can help attract pollinators and beneficial insects, as in this South Dakota field.
– Photo by Mieko Alley, USDA NRCS

a two-year cotton/corn rotation that included winter cover crops of crimson clover following cotton and a cereal rye/crimson clover/brassica cocktail following corn provided immediate financial and environmental savings [6]. Brassicas, such as mustards, oilseed radishes, tillage radishes, canola and others, are often part of vegetable rotations because of their role in managing soil pests.

There are other examples of successful rotations. In Ohio, a typical corn/soybean rotation might include the cover crops cereal rye, wheat, cowpea and sunn hemp [19]. Brassicas are also an option for a winter cover crop. In Missouri, it is possible to double-crop buckwheat or sunflowers after harvesting a winter crop of canola or wheat in early summer [20]. After winter wheat, Michigan State University Extension recommends the soil-improving cocktail of annual ryegrass/red clover/hairy vetch/oilseed radish to add nitrogen, reduce compaction and improve tilth [21]. Alternatively, the cocktail of crimson clover/annual ryegrass provides many of these same benefits, minus the soil aeration, and is also excellent pasture [21].

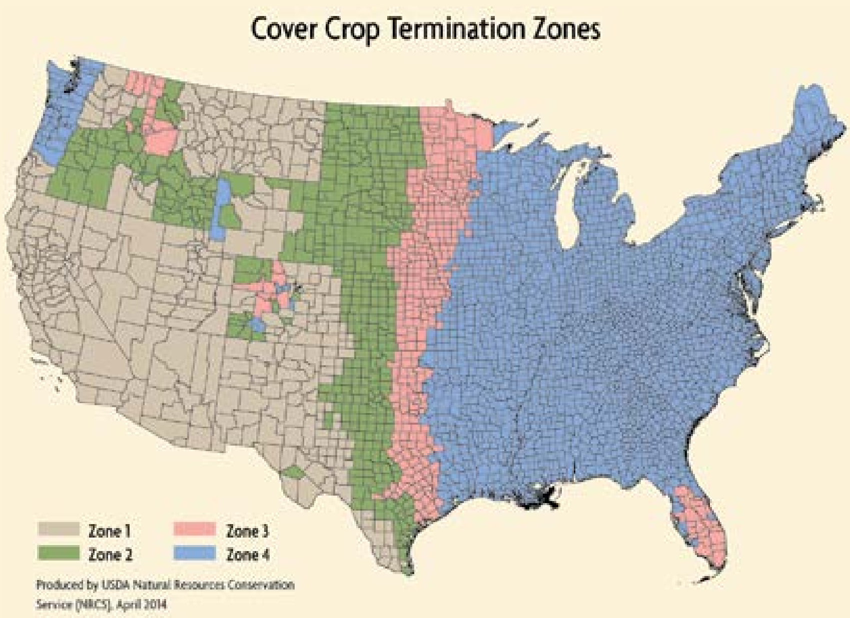
A new, cost-efficient rotation is meadowfoam (*Limnanthes alba*), a winter annual, following seed grasses. Grown in northern California and Oregon, meadowfoam over-winters as a rosette. Its dense flowers attract pollinators and beneficial insects in the spring. This emerging species is useful as both a cover crop and an oilseed. The oil produced is highly shelf stable, and is quite valuable to the cosmetics industry. However, seeds can be hard to find.

Balancing Insect Conservation with USDA Crop Insurance Rules

THE USDA'S NRCS, RISK MANAGEMENT AGENCY (RMA) and Farm Service Agency (FSA) came together in 2014 to develop standardized termination recommendations for non-irrigated cover crops in four different regions or zones in the United States [12]. They sought recommendations that would achieve optimal balance between conservation benefits and soil water conservation for cash crops, and would provide consistent guidance for cover crop policy across the three agencies. For the purpose of crop insurance, cover crops must be terminated according to these recommendations in order for the following crop to receive insurance coverage. California and the Intermountain West (zone 1) require the longest gap between cover crops and a cash crop, with a recommended cover crop termination date at least 35 days before planting. For much of the country's bread basket, the Central Plains (zone 2), farmers should terminate the cover crop at least 15 days before planting. In the eastern prairie states and south Florida (zone 3), cover crops can be terminated at planting. Finally, in the eastern states (zone 4), growers can terminate cover crops up to five days after planting, but before cash crop emergence.

A major challenge of these rules is the loss of pollen and nectar resources when cover crops are terminated before they have fully bloomed. Even when partial bloom occurs, rapid termination of that bloom results in boom and bust conditions for insects. To mitigate some of the impact of early termination, consider supplementing cover crops with other pollen and nectar resources such as hedgerows, permanent wildflower meadows, or other high-quality natural areas. Similarly, consider leaving small sections of the field (even a single outer row) in the cover crop, rather than terminating it entirely. Even such small sections can help sustain pollinators in the absence of other forage sources.

For current guidance on cover cropping and federal crop insurance, consult your local NRCS office or crop insurance program agent, or see "NRCS Cover Crop Termination Guidelines" [12] in the References section.



Relative Value of Cover Crop Species to Bees and Other Beneficial Insects

Cover Crop	Life Cycle	Seeding Rate (pounds/acre single species)	Seeding Depth (inches)	Honey Bee Value	Wild Bee Value	Beneficial Insect Value (predators and parasitoids)	Alternative Host of Crop Pests	Notes
GRASSES								
Annual ryegrass	Annual	10-20	½	None	None	Low	Unknown	Probably only useful to beneficial insects when included as part of a diverse seed mix
Barley	Annual	60-125	1½	None	None	Low	Oat and Russian wheat aphids, various small grain diseases	Best adapted to dry, cool (but not cold) climates
Millet (foxtail, proso and pearl)	Annual	5-25	½	None	None	Low	Unknown	Seeding rates for foxtail millet can be reduced to the lower end of the described range
Oats	Annual	60-120	1½	None	None	Low	Oat and Russian wheat aphids, various small grain diseases	Cool-season plant; limited cold tolerance with most varieties subject to winter kill in cold climates
Rye, cereal	Annual	60-120	1	None	None	Low	Russian wheat aphids, various small grain diseases	Potentially allelopathic to other crops
Sorghum/ sudangrass	Annual	10-40	1	None	None	Moderate	Corn aphids	Attractiveness to grass-specific aphids may make this a useful insectary plant for attracting aphid predators (in non-grass crop systems); lower end of seeding rates are appropriate for sorghum and sorghum-sudangrass hybrids; potentially allelopathic to other crops
Teff	Annual	5-10	¼	None	None	Low	Unknown	Seed may have limited availability
Triticale	Annual	60-120	1	None	None	Low	Russian wheat aphids, various small grain diseases	Potentially allelopathic to other crops
LEGUMES								
Alfalfa	Perennial	10-25	¼	High	High	Moderate	Pea aphids	Top honey plant, also attractive to large numbers of diverse wild bees
Birdsfoot trefoil	Perennial	5-10	¼	Moderate	Moderate	Moderate	Spittlebugs, alfalfa plant bugs, potato leafhoppers and others	Can be weedy and invasive
Clover, berseem	Annual	8-20	¼	High	High	Moderate	Likely a host for various leafhoppers, true bugs and generalist aphids	Best adapted to Mediterranean climates
Clover, crimson	Annual	15-25	¼	High	High	Moderate	Pea aphids, tarnished plant bugs	Grows very well in combination with cereal rye and other cool season grasses
Clover, kura	Perennial	5-15	¼	High	High	Moderate	Various leafhoppers, true bugs and generalist aphids	Poor seedling vigor and slow to establish; considered a top honey plant

Clover, red	Perennial	5-20	¼	Moderate	High	Low	Various leafhoppers, true bugs and generalist aphids	Typically short-lived; high value for bumble bees
Clover, rose	Annual	10-25	¼	Moderate	High	Moderate	Various leafhoppers, true bugs and generalist aphids	Excellent bumble bee plant
Clover, strawberry	Perennial	5-15	¼	High	High	Moderate	Unknown	Can be weedy and invasive
Clover, subterranean	Annual	10-20	¼	None	None	Low	Pea aphids, tarnished plant bugs	Flowers are inconspicuous and do not attract pollinators
Clover, white	Perennial	5-15	¼	High	High	Moderate	Various leafhoppers, true bugs and generalist aphids	Considered a top honey plant
Chickpea	Annual	80-120	1½	Low	Low	Low	Pea borers, wireworms	Beneficial insects are attracted to extrafloral nectaries
Cowpea	Annual	30-90	1	High	High	High	Various stink bugs, leaf-footed bugs, aphids	Extensive extra-floral nectaries attract large numbers of beneficial parasitoid wasps as well as other beneficial insects
Fava bean	Annual	80-160	3	Low	Moderate	Moderate	Unknown	
Lablab	Annual	30-40	1-4	Moderate	Moderate	Moderate	Unknown	Vining growth habitat; more common in subtropical climates
Lupin	Annual	40-120	1-2	Low	Moderate	Moderate	Unknown	
Medic	Annual (a few species are perennial)	10-20	½	Low	Low	Low	Alfalfa weevils, pea aphids, tarnished plant bugs	Small, nondescript flowers attract few beneficial insects
Partridge pea	Annual	10-20	¼-¾	Moderate	High	High	Various leafhoppers	Extensive extra-floral nectaries attract large numbers of beneficial parasitoid wasps
Pea, field	Annual	50-100	2	Low	Low	Low	Tarnished plant bugs	
Sainfoin	Perennial	40-80	½	High	High	Moderate	Unknown	Considered a top honey plant
Soybean	Annual	35-120	1	Moderate	Moderate	Moderate	Wireworms, bean leaf beetles, potato leafhoppers and various others	
Sunn hemp	Annual	20-40	¾	Moderate	High	Moderate	Unknown	Attracts wild carpenter and leafcutter bees in tropical farm systems; supports parasitoids of corn earworm in the Pacific Islands region
Sweet clover	Biennial	6-20	½	High	High	High	Unknown	Considered a top honey plant; may be weedy or invasive in some areas
Vetch	Annual; perennial	15-30	½-2½	Moderate	High	High	Pea aphids, tarnished plant bugs, two-spotted spider mites	Standard options include common vetch, hairy vetch and purple vetch; may be weedy or invasive in some areas

Relative Value of Cover Crop Species to Bees and Other Beneficial Insects cont.

Cover Crop	Life Cycle	Seeding Rate (pounds/acre single species)	Seeding Depth (inches)	Honey Bee Value	Wild Bee Value	Beneficial Insect Value (predators and parasitoids)	Alternative Host of Crop Pests	Notes
FORBS/BROADLEAVES								
Beet	Biennial	6-10	1	Low	Low	Low	Unknown	Wind-pollinated flowers are only marginally attractive to bees
Buckwheat	Annual	30-80	1	High	High	High	Tarnished plant bugs	Top honey plant with nectar flow typically occurring in the morning; shallow flowers attract parasitoid wasps
Canola	Annual	3-10	½	High	High	High	Flea beetles	Excellent honey plant
Chicory	Perennial	3-5	½	Low	Low	Low	Unknown	Flowers are considered self-fertile and attract few insects
Flax	Annual	25-50	¾-1½	Moderate	Moderate	Moderate	Unknown	Reports of bee attractiveness vary; probably most valuable to pollinators as part of a diverse mix
Kale	Biennial	3-10	½	High	High	High	Cabbage loopers, flea beetles, cabbage aphids	Aphid-susceptible varieties likely support the more predatory insects such as lady beetles and lacewings; rapid-blooming varieties most beneficial to bees
Mustard, tame	Annual	5-20	½	High	High	High	Flea beetles	Can be weedy and invasive in California
Phacelia	Annual	5-15	Surface	High	High	High	Tarnished plant bugs	Major honey bee nectar plant; produces volunteer seedlings in moderate climates
Radish	Biennial	8-20	¼	High	High	High	Club root of brassicas, flea beetles, cabbage aphids, root maggots	Deep-rooted varieties are promoted for reducing compaction and adding soil organic matter; not tolerant of prolonged freezing
Safflower	Annual	25-35	1	Moderate	Moderate	Moderate	Sunflower head moths, tarnished plant bugs, wireworms	Relatively drought tolerant with surprisingly deep tap roots (in some cases exceeding 8 feet)
Sunflower	Annual	4-6	½	High	High	High	Sunflower head moths, various beetles, tarnished plant bugs	Both flowers and extra-floral nectaries attract huge numbers of pollinators and beneficial insects, in most cases outweighing any risk of attracting pests
Turnip	Biennial	2-12	½	High	High	High	Club root of brassicas, flea beetles, cabbage aphids, wireworms, cabbage loopers	Turnips tend to be more cold tolerant than radishes, allowing them to flower in the spring unless terminated

Limitations of Cover Crops

YOU MAY BE ASKING YOURSELF, "IF COVER CROPS ARE so great, why doesn't everyone use them?" While some farmers may not know where to start, perhaps the greater barrier to adoption is that the financial and environmental benefits of cover cropping oftentimes accrue gradually [22, 23, 24], while the startup costs in time and money are immediate. State and federal agricultural incentive programs which offset this initial investment can be very successful in encouraging the use of cover crops [22].

Of course, not all systems are equally suited to cover cropping. In some cases, existing long-season cash crop rotations may not be compatible with cover crops. In other regions, a cover crop's water usage may hurt cash crop yields [23]. This impact can be mitigated to some extent by terminating a cover crop well prior to establishing a cash crop, allowing soil water to recharge. Additionally, over the long term, cover crops increase soil organic matter, soil water infiltration and soil water capacity. Initial declines in available water are often offset by later, long-term increases [23].

Other limitations of cover crops include expenditures for new equipment, more complicated management practices and time spent seeding and terminating cover crops rather than managing cash crops [23]. It is important to run the figures for your own operation to decide if cover crops are right for you. Should you decide that the benefits outweigh the drawbacks, plan to ease into cover cropping, starting with a small area and gradually expanding your cover cropped land as you get the hang of it.

John Hayden tested a summer cover crop of buckwheat for its ability to suppress weeds and attract bumble bees, an important pollinator on his Vermont fruit farm. It worked well, and after going to seed did not return in the spring as a weed. *– Photo by Nancy Hayden*

Beyond Cover Crops

ALTHOUGH COVER CROPS CAN PROVIDE SIGNIFICANT pollen and nectar resources for bees, they do have constraints. For example, because most cover crop species have a short bloom period, single species cover crops typically offer a feast-or-famine situation for bees. A shortage of food is followed by abundance, followed by another shortage. Under such circumstances wild pollinators may have trouble sustaining their populations. (Honey bees may be more resilient under such conditions due to their ability to store food reserves.)

Moreover, because most cover crop plants are non-native species, their attractiveness to wild native bees may be highly variable. The cover crops highlighted in this bulletin will attract mostly generalist species of wild bees that are relatively common in most landscapes. Less common species of native bees often require more permanent plant communities comprised primarily of native plant species. In general, to maximize the diversity and abundance of beneficial wild insects, flowering cover crops should be combined with the restoration and maintenance of permanent, high-quality, pesticide-free native plant habitat in other areas of the farm. Adding pollinator hedgerows, establishing pollinator plantings on marginal lands and borders, and other practices to boost habitat can all fit into other USDA conservation practices.

Regarding pollinator borders specifically, two SARE-funded research projects in Michigan demonstrated the value of permanent native wildflower strips adjacent to crops. In one of these studies [25], researchers found that corn borer egg parasitism was measurably higher in fields adjacent to perennial native wildflower strips. In the other study [26], researchers found that blueberries planted adjacent to perennial wildflower strips had berries that were 22-40 percent heavier, due to enhanced pollination by wild bees.

Insecticides and Insect Conservation

You can reduce risk to pollinators and beneficial insects by implementing IPM on your farm and only applying insecticides when the threshold for economic damage has been crossed.

INSECTICIDES SHOULD NOT BE APPLIED TO COVER CROPS where pollinator and beneficial insect conservation is a priority. In most cases it is unnecessary, regardless of your cover crop objectives. Both organic and conventional pesticides can harm pollinators and other beneficial insects. Cover crops are themselves often used to break pest cycles and manage nematodes, and can help reduce your overall use of insecticides.

However, where cover crops are planted in rotation with insecticide-treated cash crops, the residual impact of cash crop insecticides may still be a concern. You can reduce risk to pollinators and beneficial insects by implementing IPM on your farm and only applying insecticides when the threshold for economic damage has been crossed. You can also start your course of treatment with the least harmful insecticide that will accomplish your management need. You can reduce harm to good bugs from insecticides by following label instructions, avoiding the application of insecticides to flowering plants, spraying at dawn or dusk and by using chemicals that have low residuals and do not accumulate in the soil or plant.

Unfortunately for beneficial insect conservation, there are a number of widely used systemic insecticides with persistent chemical residues in soil and plant matter. Systemic insecticides are those which are absorbed into the plant tissue and move through the vascular system of the plant, making most parts of it toxic to insect pests. In some cases the insecticide may even be present in flower nectar, resulting in the lethal or sublethal poisoning of bees and other pollinating insects.

The most common class of systemic insecticides currently in use is neonicotinoids. These include the active ingredients imidacloprid, thiamethoxam, clothianidin, acetamiprid, thiacloprid and dinotefuran. These insecticides may be applied in crop fields as foliar sprays, root drenches and as seed treatments (the latter commonly used for corn and soybeans). They can persist in the soil and crop residue for multiple years, and can be reabsorbed by later crops that were not treated. Due to a growing body of research demonstrating the potential risk posed to pollinators and beneficial insects from neonicotinoid insecticides [27, 28, 29, 30, 31], and our knowledge of neonicotinoid crop residues, farmers should avoid planting cover crops in rotation with neonicotinoid-treated cash crops where possible, especially when bee and beneficial insect conservation is a goal. Instead, producers should focus their conservation efforts on other areas of the farm which are untreated. It is also important to request and use cover crop seed that is untreated with pesticides.

Following the precautionary principle means that we should not put beneficial insect habitat on lands contaminated by systemics—that is to say, in the absence of scientific proof that residue from previous use of systemic insecticides does not harm pollinators, it is safer to assume that it does. Growers of conventional corn and soybeans could instead focus their insect conservation efforts on hedgerows, roadsides and other areas not sprayed with systemic insecticides. They could also make their preference for untreated seed known to their supplier. In 2014 the Environmental Protection Agency (EPA) confirmed that there is little to no benefit from pre-treating soybeans; if enough growers request untreated seeds, then it is likely more will become available.

Similarly, cover crops should not be directly treated with any class of insecticide. An exception would be in the case of a cover crop being used for another primary purpose, such as livestock forage, where it must be protected from catastrophic pest damage. However, treatment of cover crops with insecticides is rare. Furthermore, it is critical to protect cover crops from adjacent insecticide drift. Any use of insecticides should fully adhere to label recommendations.

Avoiding Pest Increases

WHILE ADDITIONAL RESEARCH IS NEEDED, THERE IS strong evidence that diverse cover crop cocktails will routinely reduce pests, by increasing populations of beneficial predatory and parasitoid insects. In contrast, single-species cover crops may increase populations of undesirable crop pests, by providing a more limited range of resources than plantings which can support a diverse population of predators.

To further reduce the possibility of increasing crop pests, use caution when considering cover crops that are closely related to cash crop species. For example, if brassicas such as broccoli or cabbage are primary cash crops, minimize the use of cover crops such as turnip, radish or mustard, all of which may host the same pests and diseases as the cash crops.

During their SARE-funded project, the Haydens observed that the pure stand of phacelia provided habitat for the tarnished plant bug, a pest of tree fruits and berries. “From what we have learned, we will continue to plant multi-functional cover crops timed to bloom in July and August,” Nancy Hayden says.

RESEARCH CASE STUDY: USING COVER CROPS TO INFLUENCE NATURAL PREDATION OF COTTON PESTS

AMONG LARGE-SCALE FIELD CROPS, COTTON IS high on the list for susceptibility to multiple major pests. Cotton bollworm, tobacco budworm, cotton aphid, tarnished plant bug and various stink bugs are some of the biggest offenders for cotton growers in the Southeast. Any management strategy that can make a dent in the populations of these pests without relying on insecticides is good news.

One such successful strategy came about through a SARE-funded research project in Georgia [32] that investigated the use of cover crops to increase the number of insect predators that prey upon some of those pests. This research was based on the fact that many beneficial insects need alternate food sources, such as nectar, to sustain themselves when prey are absent. These beneficial insects also typically need vegetation on which to lay eggs or hibernate over the winter. In this study, researchers hypothesized that various cover crops might provide those habitat requirements.

Starting with standard cotton fields where cover crops were not used, the researchers compared pest and beneficial insect populations to those in cotton fields where cover crops of crimson clover, cereal rye and a legume mix were used in rotation and as intercropping cover. For a few beneficial insects like the predatory minute pirate bug, there was not a significant population difference between traditional cotton fields and those with cover crops. However, most pest and beneficial insect population responses strongly indicated that cover crops had a measureable and positive impact on pest management. For example, predatory big-eyed bug numbers were demonstrably higher in cotton fields following a crimson clover cover crop. Aphid-eating lady beetles also seemed to move directly from cover crops into cotton.

In the case of pests, researchers also found that cotton bollworm and tobacco budworm were the only two pests that exceeded economic thresholds in both the cover cropped fields and the regular cotton fields. Interestingly however, the pests exceeded those damage thresholds more often in regular cotton fields than those where crimson clover and rye cover crops were used.

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Resources

Cover Crops for Sustainable Crop Rotations
This online collection of educational materials was developed out of decades of SARE-funded cover crop research. www.sare.org/cover-crops.

Attracting Native Pollinators
Illustrated with hundreds of color photographs and dozens of specially created illustrations, this book provides rich detail on creating and managing pollinator habitat. www.xerces.org/store/#books.

The USDA-NRCS Cover Crop Economics Tool
This user-friendly economic assessment tool helps determine the costs and benefits of incorporating cover crops into a crop rotation. www.nrcs.usda.gov/wps/portal/nrcs/detailfull/il/soils/health.

Manage Insects on Your Farm: A Guide to Ecological Strategies
A guide on how to apply ecological pest management principles to your farming system. www.sare.org/manage-insects.

Managing Cover Crops Profitably, 3rd Edition
This book explores how and why cover crops work and provides all the information needed to build cover crops into any farming operation. www.sare.org/mccp.

Midwest Cover Crop Council - Cover Crop Decision Tool
An online tool to assist farmers in selecting cover crops in field crop and vegetable rotations. http://mccc.msu.edu/selector-tool/.

Bees and Cover Crops
This four-page Penn State bulletin describes the use of flowering cover crops for native pollinator conservation. www.sare.org/native-bees-and-flowering-cover-crops.

Habitat Management in Vineyards
This University of California manual provides practical steps for managing pests by improving biodiversity at the field and landscape levels. www.sare.org/habitat-management-in-vineyards.

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