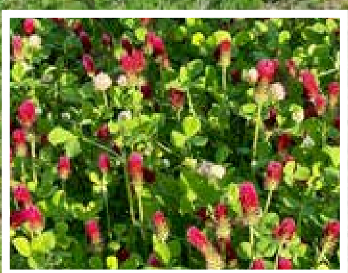
COVER CROPS

Improving Soil Health, Stewardship and Profitability on the Farm



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Sustainable Agriculture Research & Education
HANDBOOK 18

Robert L. Myers

2nd Edition

COVER CROPS

Improving Soil Health, Stewardship and Profitability on the Farm

Robert L. Myers, Ph.D.

SARE handbook series 18

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DEDICATION

I’m dedicating this book
in honor of my dad
a life-long farmer who taught me
about cover crops as a young boy
and inspired me to pursue
a career in agriculture.

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Preface

My introduction to cover crops came from my dad in the late 1960s, while I was growing up on our family grain farm in central Illinois. My dad was primarily growing corn and soybeans at the time, but he also grew some winter wheat that he would interseed with a cover crop of sweet yellow clover in early spring. After the wheat was harvested for market, the small clover plants took off, growing rapidly and forming a lush layer of vegetation by fall. The clover would be left untouched in order to protect and improve the soil until the following spring, at which point it would be turned under as a green manure–a crop grown specifically to fertilize the soil–with a moldboard plow, before disking and preparing the field for corn planting.

One time when we were out in the fields, my dad pointed out a plot of corn that had been grown after the clover cover crop and remarked on how much better it looked than the adjacent plot, where there had been no cover crop; the corn's leaves were a darker green, and its ears were more robust. Further, while my dad was noticing the corn's superior health following the clover cover crop, I was noticing something else: a greater-than-usual number of rabbits, foxes, hawks, quail, pheasants, and other animals that attracted my attention as an outdoors-loving kid. Those clover fields ended up being my preferred place to spend time tromping around with my dog, because they held the most fascinating diversity of life out of anywhere on the farm.

Although my dad believed in the benefits of cover crops, as crop prices changed in the 1970s, he stopped growing wheat, and thus the sweet yellow clover cover crop disappeared from our rotation. The other factor that had motivated my dad to use cover crops was our elderly landlord, who had done most of his farming in the era prior to World War II when synthetic fertilizers were expensive and not as commonly used. This landlord, Harry Griswold, had farmed with cover crops for decades in the first half of the 20th century, and had always encouraged my dad to keep at least 10%-20% of the farm in legume cover crops to improve the soil. After Mr. Griswold's passing and the change in markets, cover crops left our farm for almost 40 years, not returning until 2013 when our current tenant, Cory Ritter, started using them again. After Cory got a few years of experience with cover crops on a small acreage, he expanded their use to all the land my mom still owns, with support from a Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) 3-year contract that provided funds to pay for the cover crop seed. My dad passed away in late 2014, but had given his blessing to the return of cover crops to the farm after attending a cover crop workshop put on by the Soil and Water Conservation Society.

In the meantime, I had gone on to study crop and soil science in college and graduate school. In 1989, I accepted a faculty position in agronomy at the University of Missouri to work on diversified cropping systems. With graduate student John Fisk, I studied the impacts of several different cover crop species on various row crops in the early 1990s. At the time, very few farmers or researchers were paying any attention to cover crops; I remember a time in 1993 when we organized a meeting for other people at the university who we thought might be interested in cover crops, and only a few of them joined us (I repeated that effort in 2014 with considerably more success–over 120 people from the university and state agencies attended the meeting, reflecting the remarkable growth of interest in cover crops).

In early 1995, I went to work at the United States Department of Agriculture (USDA) headquarters in Washington, D.C. as the National Program Leader for Sustainable Agriculture. One of the most enjoyable aspects of that job was meeting farmers from across the U.S. who were working to improve the sustainability of their farming operations, and having the privilege of visiting dozens of their farms. Some of those farmers were using cover crops and enthusing about their ecological and economic benefits. For example, Steve Groff, a farmer in Pennsylvania, was an early cover crop advocate whom I met in 1995 and has since had a big impact on me. Steve's expertise and passion for cover crops grew so strong that he became one of the most sought-after cover crop speakers around the world, and his family farm has arguably been the site of more cover crop trials than any other private farm in the U.S. Hearing the experiences of farmers like Steve encouraged me to continue learning about cover crops, and we were able to make cover crops a priority within the Sustainable Agriculture Research and Education (SARE) program that I managed for the USDA. Over the years, SARE has funded over 1,000 projects on cover crops led by universities, nonprofits, and farmers.

Although I enjoyed working with SARE, my wife and I wanted to raise our kids closer to family in the Midwest, so we returned to Missouri after three years in D.C. Once back, I re-engaged in field work with diversified cropping systems, including a variety of alternative crops and cover crops. Some of the plants I worked with, like buckwheat, millets, canola, cowpeas, and sunn hemp, had potential both as economic crops and cover crops; other plants I worked with were used solely as cover crops, like several of the clovers and winter cereals. Over the years, I've had the chance to grow over 30 species of cover crops in the field. My personal favorite cover crop, crimson clover, is one I've grown in plots of various sizes for over 20 field seasons, and every year I try to grow and observe a variety of cover crops.

Cereal rye protecting and improving the soil in spring.

In 2010, I returned to work with SARE, focusing on the North Central (Midwest) region. I continue to work with SARE as the North Central Region Director of Extension Programs, and also direct the Center for Regenerative Agriculture at the University of Missouri. In both of these roles, cover crops and soil health have been a major emphasis area of my work.

I won't recount all the meetings, publications, videos, and other activities I've been involved with on cover crops, but will simply say it's been heartening to see the tremendous growth of interest in cover crops and the many people who have become passionate advocates for growing cover crops. While I firmly believe farmers have led the way in the current cover crop boom, there's no question that many NRCS staff, soil and water district employees, researchers, Extension agents, crop consultants, and nonprofit educators have helped move cover crops forward. The role of the private sector has been of particular importance, including the work of many small and midsize cover crop seed companies to provide not only high-quality seed, but also high-quality information about cover crops.

While much has been written about cover crops, particularly in the realms of fact sheets, Extension bulletins, industry publications, research reports, and farm magazine articles, I felt there was a need for a book summarizing some of the latest insights from farmers and others on cover crop use and management. I hope this book will be of interest to a wide range of individuals interested in cover crops, but I have focused it primarily on farmers. I've tried to share information in a way that will be helpful to farmers who have not yet tried cover crops, as well as those who are using them but continuing to experiment with what works best for their farm.

Cover crop management continues to evolve, and I have no doubt that a decade from now, we'll see continued expansion of cover crop use and further innovation in cover crop strategies. For now, I hope this book will be helpful to those of you looking for more information on the fascinating topic of cover crops and ideas on soil health management approaches that can provide many benefits to our fields, farms, and food systems.

I want to close this preface by saying this book was a family effort, with excellent contributions to editing and layout by my daughter Haley and thorough proof-reading by my wife Amy. I am indebted to them for all their time in helping to complete this book.

Rob Myers
Columbia, MO

CHAPTER 1

How cover crops can fuel our farms

Think of all the energy that goes into a farm's operation: fuel to run tractors, combines, and trucks; electricity to power shops and homes; and propane for heat and grain driers. All that energy pales in comparison to the amount of energy that hits our farms in sunlight.

We already harvest a good portion of that sunlight through the photosynthesis that feeds our crops. However, when we only grow cash crops for four to five months of the year, we fail to capture as much of this free resource as we could. By letting the sun fall on idle ground for the majority of the year, we miss out on fueling the underground carbon exchange–an economy of sorts that Nebraska farmer and seedsman Keith Berns has called "carbonomics." The players in this underground carbon economy on our farms are earthworms, soil fungi, bacteria, arthropods, and other organisms, as well as the plant roots that catalyze the whole underground carbon exchange.

When powered by sunlight, plants such as cover crops can generate extra carbon in the form of carbohydrate exudates–typically sugars that they exude into the soil from their roots. The plant roots evolved to do this in order to gain nutrients, and sometimes water, back from fungi and bacteria in the soil. If we don't have living roots in the soil, this carbon exchange grinds to a halt, which is why some farming approaches can lose soil carbon and soil organic matter.

It's as if we had bought a herd of cattle in the summer, fed it for a few months until October, then forgot to feed those animals from fall to spring. We would be letting a valuable farm resource go to waste, and that's what happens when our underground "livestock" herd isn't being fed by sunlight and plant roots: the soil microbe herd starts to lose weight and its members begin to die off. When these soil critters are dead or dormant, they can't do any work for us, such as building soil organic matter and recycling soil nutrients in a form that our cash crops can use.

Another relevant analogy is to think of the soil ecosystem like a finely tuned truck engine: if you take away the fuel from the engine–which in this case is the living roots needed for carbon exudates–the engine stops running. Or, if you damage the engine by overworking it–in this case over-tilling or compacting the soil–you will also prevent it from running efficiently. A poorly running truck engine makes it hard to get anywhere, and the same can be said of how soil health affects the economic success of the farm. We need the soil functioning at peak performance, and that means managing soil carbon and building soil health to an optimal level in each field.

The good news is that many farmers have been finding ways to increase their soil performance with cover crops. In this book, we'll take a look at straightforward and simple ways of using cover crops in order to build soil health and farm wealth. We'll examine how cover crops can impact a farm's economic bottom line and help achieve farm goals, including leaving the farm in better shape for those who follow you.

While many readers of this book may already be familiar with common cover crops, a quick definition of what exactly cover crops are may perhaps be helpful. Cover crops are plants grown to protect and improve the soil, especially when no cash crop is being grown. Cereal rye is the most common cover crop, grown on about half of all cover crop fields either as the sole cover crop or as part of mixes with other cover crops, but over 40 species of cover crops are currently sold in the U.S. In addition to cereal rye, other common fall-planted cover crops include legumes such as crimson clover, hairy vetch, and Austrian winter peas; Brassicas such as radishes, turnips, and canola/rapeseed; and a variety of small grains such as oats, wheat, triticale, annual ryegrass, and barley. There are also a wide variety of summer cover crops, including millets, cowpeas, sunn hemp, and buckwheat.

Some specific topics covered in this book include:

- How to make money off of cover crops
- Ways to save time when using cover crops
- How cover crops will build soil health
- Simple steps for getting started with cover crops
- Equipment strategies and options for managing cover crops

- Combining cover crops with other practices to increase farming efficiency
- Potential issues with cover crops and how to avoid them

One part of this book sure to be of interest is the stories of a dozen farmers who are already using cover crops and how they have fit them into their farm operations. Farms from several parts of the U.S. are included, so hopefully you can find examples relevant to your area. Keep in mind that well over 150,000 farmers in the U.S. are currently using cover crops on at least part of their acreage; going to a field day on cover crops is a good way to meet other farmers in your area who are using them and connect with farm advisors interested in cover crops.

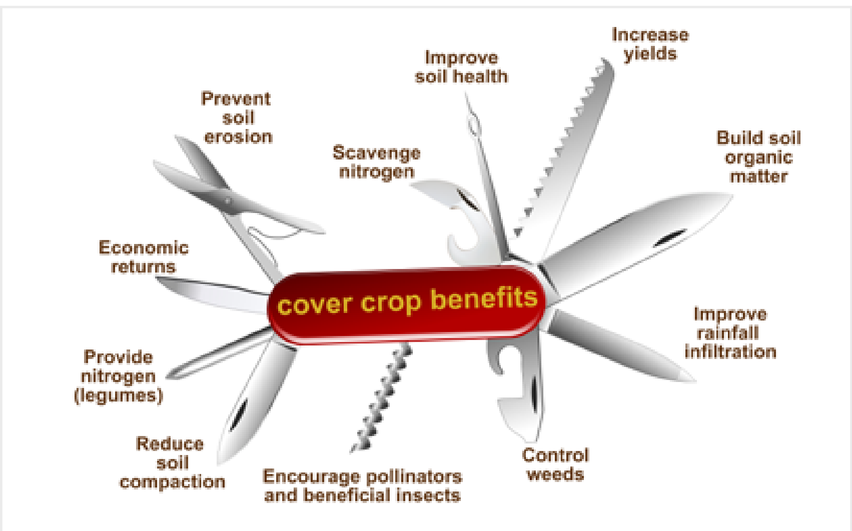
From talking with many farmers who are using cover crops, including those profiled in this book, I've learned that most had specific reasons for using them. For some farmers, cover crops are a way

A farmer examines soil structure in a field.

of managing weeds or improving soil fertility. For others, they are a way to address compaction or rectify a poorly-performing field. Some decide to give cover crops a try after hearing from a neighbor having success or learning about cost share support. Regardless of why they got started, most of these farmers say they will stick with cover crops for the rest of their farming days because they are seeing so many benefits.

In thinking about the reasons cover crops are used, it struck me several years ago that cover crops are like a Swiss Army Knife because they are such a highly versatile tool. In fact, I can't think of any other agronomic practice that can provide so many different benefits. We had the following illustration developed through the USDA Sustainable Agriculture Research and Education (SARE) program to point out all of the various benefits that cover crops can provide. Even if only one or two of these benefits seem particularly relevant to you, it can be worth giving cover crops a try on a field or two.

If you're one of those people who have been hesitating to try cover crops, test them on a single field to start with. But give the practice a fair shot at success–follow some of the tips in Chapter 6, "Simple



Illustrated by Carlyn Iverson. Illustration provided courtesy of the USDA-SARE program.

steps for getting started with cover crops." You should be able to find an approach that's easy for you to fit into your operation and helps you achieve particular field goals you have, such as managing herbicide-resistant weeds, dealing with compaction, or just improving the soil's performance, especially in dry weather.

If you are just getting started with cover crops, even though your closest neighbors may not have tried them yet, rest assured that you are not alone. At the time of this book's writing, cover crops were being used in every region of the country on over 20 million acres. Some farmers plant their whole farm to cover crops, and others are more targeted with where they use them, such as in poorer soils or more steeply sloping fields. Don't feel like the whole farm has to be planted to cover crops right away; the main thing is just to get started. You know the saying: every journey begins with a single step!

What Farmers Are Saying

I want to end this first chapter with some direct quotes from farmers using cover crops. These comments were compiled from the National Cover Crop Survey (which is why they are anonymous), and include valuable insights from farmers who are making use of covers.

Some of these farmers own and some rent the land they farm. If you are renting farmland and want to discuss implementing cover crops with your landlord, it may be heartening to know that in the survey, a high percentage of respondents reported support from landowners in using cover crops on rented acres. In fact, some farmers have said they find it makes it easier to rent additional ground when they explain to landowners why they use cover crops and how they can improve the ground of that landowner. In a time of competition for land, being able to demonstrate that you are a stewardship-minded producer who works to build soil health can pay big dividends both on your own ground and with landowners you may be working with.

Here's what some farmers using cover crops said they would like to tell their neighbors–I expect some of these ideas will resonate with you. I believe these reasons reflect why we have over 20 million acres of cover crops in the U.S. today, and why the adoption of cover crops has been steadily increasing.

- "Cover crops will save and even rebuild your soil. There is a place for a cover crop in every operation, and the benefits will accumulate over time."
- "It is a systems approach based on a return to the way nature is intended to work, and therefore can be extremely successful."
- "Through use of cover crops, we are able to better meet the biological needs of our soil. Once our soil is in balance, nutrient uptake is easier for the plant and we are able to reduce disease in our crop. Ag is not only about managing our crop health, but also soil health."
- "Cover crops hold more moisture in the soil than they use."
- "Every day without live roots in the ground is a day wasted. The soil is alive and we must feed and protect it!"
- "Soil health is key. Cover crops are better than steel."
- "The use of cover crops can reduce compaction without doing deep tillage."
- "Cover crops are a long-term investment in improving your soil biology."
- "You have to think longer-term about your rotations, not just look year-to-year. That is when you realize cover crops are integral to your crop rotations."
- "Our system captures carbon, increasing organic matter. We will produce more yield with less inputs."

- “There is a wide array of cover crops that can improve every rotation and soil with a little bit of planning.”
- “Keeping the soil covered year-round provides food for the life in the soil, which in turn provides nutrients for your crops.”
- “Cover crops mimic what Mother Nature was doing before man began farming, she always kept herself covered and always had some kind of live roots year-round. The closer we can mimic this, the better our soils will become over time.”
- “By using cover crops, we will be able to recover the rich fertile living soils we once had, and we will be able to pass it on to future generations.”
- “There is room on every farm for cover crops.”
- “If you expect to be able to farm your land in 50 years, or have your child or grandchild farm it, then you need to use cover crops.”
- “We must take better care of the soil we depend on.”
- “Please use cover crops. They do work, and help in ways nothing else does.”

CHAPTER 2

Making money off of cover crops

When considering cover crops, it's natural to wonder what their financial payoff will be. In this chapter, I hope to convey the various ways that cover crops contribute to profitability. I've heard time and time again from highly successful farmers that they feel their financial bottom line is benefitting from cover crops.

When penciling out the potential costs and returns of cover crops, there are a few general points to keep in mind. First, the costs of cover crop seeding may be fairly consistent from year to year, whereas the returns from covers will not only increase over time, but are also typically greater in years when drought or other weather stress may reduce crop yields. Second, the economic effect of cover crops is defined not just by their yield impacts, but also by how they reduce costs in other parts of your operation. Third, use of cover crops usually involves other management changes that lead to improved net profitability (something addressed not only throughout this chapter, but also in Chapter 10 on combining cover crops with other soil health practices). Evaluating the full economic impact of cover crops, in other words, involves taking a holistic or systems-based perspective of the various ways that cover crops affect profit, and consideration of how your whole cropping system fits together and could be improved. It also involves thinking more than one year ahead, just as if you were evaluating whether to invest in a new piece of field equipment or whether it's worth liming or tiling a field.

To break the complex topic of cover crop economics into more digestible chunks, let's look at eight ways that cover crops can impact your profitability, plus the payoffs after one year, three years, and five years of using cover crops.[1] The rest of this chapter will address:

- Arming yourself for battle against herbicide-resistant weeds
- Enhancing fertility and nutrient management

[1] *A portion of the concepts addressed in this chapter are adapted from material I drafted in early 2019 for an in-depth SARE bulletin on cover crop economics, available as one of the publications listed at www.sare.org/covercrops.*

- Lightening the compaction load
- Dollars and sense of grazing
- Tips for cost-effective seeding and management of cover crops
- Cashing in on incentives
- Insurance for droughts and floods: winning the weather war
- What to expect in terms of yield impacts
- One-year, three-year, and five-year payoffs

Arming yourself for battle against herbicide-resistant weeds

One of the greatest emerging threats on row crop farms is the rise of herbicide-resistant weeds. If you are like most commodity farmers, you probably have herbicide-resistant weeds on at least some of your fields, and the problem is growing worse each year. Marestail, waterhemp, and Palmer amaranth are the three worst weeds to have developed herbicide resistance so far, but more weeds are gaining resistance to one or more major herbicide chemistries, particularly glyphosate. The most common approach to dealing with this problem is to apply even more herbicides, which unfortunately comes at greater cost to the farmer. While it's true that adopting an appropriate combination of residual and post-emerge sprays can help manage the problem, these common steps are sometimes ineffective at keeping all herbicide-resistant weeds in check.

Fortunately, cover crops can be used strategically as a cost-effective tool to manage herbicide-resistant weeds. Research at the University of Nebraska (Basche, 2019) found that cover crops reduced both the number and biomass of herbicide-resistant weeds by 90%. Almost any densely growing cover crop species or mix can suppress marestail, which often starts growing in the fall or early spring if no plant competition is present to prevent its establishment. Summer-emerging weeds like Palmer amaranth or waterhemp can also be deterred by the presence of a thick layer of cover crop residue.

Cereal rye in particular has been found to be successful in combination with herbicides against these weeds. It can produce a thick layer of biomass that prevents or reduces weed emergence if allowed to grow long enough. Cereal rye also produces allelochemicals that

A farm in Missouri where cover crops are being employed against glyphosate-resistant marestail. On the left, glyphosate-resistant marestail is completely controlled by cereal rye. On the right, in a strip with no rye cover crop, the marestail is thick despite having been sprayed with glyphosate. Photo by Alan Weber.

are particularly effective against small-seeded broadleaf weeds like waterhemp and Palmer amaranth, reducing percent germination and/or vigor of these weeds and making it easier to knock them out with herbicides.

The best way to use cereal rye as part of a weed control strategy is with a later-planted crop like soybeans, cotton, sorghum, or sunflowers. Allowing the cereal rye to grow 3-5 feet tall enables it to gain sufficient biomass (preferably at least three tons per acre of dry biomass) to be effective in creating a weed-suppressing mat. Of course, it's also best to plant the commodity crop no-till into the cereal rye so the residue can form a thick mat on the soil surface. In recent years, many farmers have found that planting a broadleaf commodity crop like soybeans or cotton into still-living green cereal rye, then spraying or rolling the cereal rye after planting, is the best way to use this cover crop. This "planting green" approach (see more details in Chapter 8) not only allows the cereal rye more time to grow, but also keeps furrow openers from pushing aside previously rolled or downed residue; if the planter exposes weed seeds along the furrow to light, some of those weeds will start growing. A roller or roller crimper works well either attached to the planter or in a separate pass, but many planters also do a decent job of knocking down cereal rye that is tall and in the flowering stage (at or after pollination).

Enhancing fertility and nutrient management

Before the rise of modern chemical fertilizers, cover crops were often used as "green manure" that could enrich the soil. Legumes in particular were popular for this purpose. As mentioned in the preface, on our farm in central Illinois, my father used yellow sweet clover for this purpose. The positive difference it made in the quality of our corn crop was clearly visible, and the lesson of how the clover improved the soil stuck with me.

Nitrogen fixation

In my own career as an agronomist, I've experimented with many different legume cover crops and, as with other agronomists and farmers, have found crimson clover, hairy vetch, and Austrian winter peas to be good at improving soil fertility through their nitrogen fixation. With these winter annual legumes, most of the nitrogen fixation happens during the spring, particularly from late April to June. Thus, early termination of these legumes, such as in the first half of April before corn planting, significantly limits the amount of nitrogen fixation that occurs. It can make the difference between getting less than 50 pounds of fixed nitrogen to benefitting from well over 100 pounds of fixed nitrogen from legumes that are allowed to grow until they start flowering or beyond. The best recorded nitrogen contributions from hairy vetch and Austrian winter peas have been around 150 pounds of nitrogen, but somewhat lower contributions would be more typical. Still, I've found it possible to grow crops planted around the first of June in Missouri, such as sorghum or sunflowers, without any supplemental nitrogen other than the nitrogen provided by a legume cover crop.

While it's well understood that soybeans as a summer legume contribute only a modest amount of nitrogen fixation, there are other summer legumes that are much more effective at fixing nitrogen during the warmer months of the year. Cowpeas and sunn hemp are the two most often used for summer nitrogen fixation, grown either as single species or as part of a cover crop mix, and are typically planted after winter wheat harvest or after early-season vegetables. A rotation of corn, with cereal rye in the fall then soybeans the next summer, followed by winter wheat and then a summer legume such as cowpeas or sunn hemp (with or without other cover crops in a mix) can provide more nitrogen to the following corn crop than simply using a winter annual legume that is terminated very early in April, like crimson clover or hairy vetch. Such a diverse rotation is also great for pest management and building up soil organic matter over time.

Perennial and biennial legumes can also be very beneficial from a nitrogen fixation standpoint, if allowed to grow for a year or longer. Red clover and alfalfa are the most popular legumes for rotations

Crimson clover is a popular legume cover crop in the southern Corn Belt.

where the legume will be allowed an extended period of growth. They may be hayed or grazed to make income before the field is planted back to corn at some point.

I expect we'll see additional species of legumes receive more attention going forward, as well as improved cultivars of the common legume cover crops. This will enhance not only the overall performance of cover crops in the rotation, but also potentially the amount of nitrogen they are contributing. Examples of legume species with new cultivars being used in some regions for nitrogen-fixation and overall cover crop benefits are balansa, berseem, and Persian clover. Faba beans and lentils are legume pulse crops normally harvested for seed that have begun to be used in some cover crop mixes. Some farmers are even trying perennial clovers like white clover or kura clover as low-growing covers that can grow between corn plants or other summer annual cash crops.

Predicting the amount of nitrogen that will be contributed from a cover crop to a cash crop like corn can be challenging. So much depends on the amount of growth the legume achieves. As testing for in-season nitrogen needs of corn continues to improve, I expect it will be the best way to evaluate how much nitrogen fertilizer application can be reduced following a cover crop. In general, a well-grown legume cover crop that reaches full size and flowering before planting a summer cash crop can reliably contribute at least 50-100 pounds of nitrogen per acre, providing potential cost savings on nitrogen fertilizer of $20-$40 per acre (based on Midwest fertilizer prices in 2022). Just remember that with typical early termination of legume cover crops before corn planting, nitrogen contribution will be much reduced due to lack of legume growth, and fertilizer savings will be modest at best.

Nutrient sequestration

While nitrogen-fixation from legume covers is important on some fields and farms, the bigger nutrient impact from cover crops on watersheds comes from the nutrient sequestration all cover crop species can provide. Both plants and soil organisms play a role in keeping nutrients in a field rather than exiting through tile lines or surface runoff. While summer cash crops are growing, nutrient loss is minimized. The problems with nutrient loss normally start after the cash crop is harvested and nothing is growing in the field, often until the next spring. There are no plant roots in the fall-to-spring months to take up and hold on to soil nutrients, and many soil microbes die or go dormant because they don't have living roots to support them. With no plant roots and a less healthy soil ecology, the system becomes leaky and valuable nutrients are lost, not only causing problems off-site but also causing a need for more expensive fertilizer to be purchased the next season. Soil that erodes when no cover crops are present will also carry off nutrients–a loss so consequential that it's almost as if dollar bills are blowing or washing out of the field.

Fortunately, we now know that a wide variety of cover crops can keep soil nutrients in the field and in the root zone where we want them for the next cash crop. We're still learning which cover crops are best for capturing nutrients and when those nutrients are released, but in general, the more vigorous and deeper-rooted cover crops are the ones most helpful for scavenging or sequestering nutrients. Fast-growing covers in fall–like radishes or oats–can be valuable, as can most of the winter annual cereal grasses and Brassicas.

Going forward, we need research to help us better understand which mixes of cover crops work best for releasing nutrients at the right time for the cash crop, and how best to supplement with nitrogen, particularly after winter annuals such as cereal rye. One thing we have learned is that a high-carbon cover crop like rye or triticale can be made to release its nutrients somewhat faster (and achieve faster biomass breakdown) if combined with a high-nitrogen cover crop like a legume or Brassica. The challenge is getting enough growth of a legume or non-cereal in a stand of vigorously growing rye to accelerate the release of rye nutrients the following summer; it helps to cut back substantially on the rye seeding rate when using it in mixes. Keep in mind the goal of achieving more rapid breakdown of rye residue may be counter to keeping the residue in place for weed control or moisture retention reasons.

In sum, cover crops that can sequester nutrients, particularly nitrogen, can provide cost savings in the amount of fertilizer required for a following crop. This amount will be modest, perhaps $10-$15 per acre, but when added to other economic benefits of the cover crop, it can provide a significant positive return.

Extra soil nutrients from increased soil organic matter

The economic savings from soil fertility changes discussed above can occur quickly, within the first year of cover crop use. In the longer-term, the gradual increase in soil organic matter from consistently using cover crops can pay big dividends as well. A soil that is boosted by 1% in organic matter, such as from 2%-3% organic matter, will contain roughly an extra 40 pounds of nitrogen and 20 pounds of phosphorus and potassium per acre. This is because the stabile fraction of organic matter is always releasing some nutrients to plant roots through the action of soil microbes. The economic contribution from an extra 1% of organic matter can be estimated at approximately $35-$40 per acre (based on 2022 fertilizer prices), and that's not including the significant value of the extra organic matter for improving soil moisture–see more on this topic later in this chapter.

Lightening the compaction load

If you use large combines, trucks, or tractors, you have probably experienced compaction problems in at least some of your fields. Presumably, you've had to spend time and money doing deep tillage operations in an attempt to remedy those yield-robbing compaction issues. However, as you may have heard, ripping or other deep tillage operations are often ineffective at providing a long-term solution to compaction, as clay subsoils tend to swell ripped furrows closed in the months following the action of the ripper.

Farmers are increasingly finding that the best long-term solution to compaction is to use biological solutions that help build soil structure and improve aeration. Research at Ohio State University by Alan Sundermeier and Randall Reeder showed that cover crops were more effective at relieving compaction problems than using deep tillage. In the short term, cover crops created more macropores in the soil both from their roots and by stimulating earthworm activity. The increased number of macropores, especially under minimum-till situations, provided improved drainage and aeration of compacted soils. In the longer term, cover crops and the microbes they support build improved soil structure by increasing soil aggregation. This improved structure serves not only to provide strength to soils but also to add pore space for better aeration.

In fact, cover crops can help offset the potential short-term compaction issues that might otherwise come from moving to no-till or adding grazing to a field. The no-till advantage is discussed at greater length in Chapter 9, but suffice to say that combining no-till and cover crops creates a synergy in soil management that improves soil structure even more than using either practice alone. Likewise, cover crops in a field make it more feasible to have cattle in the field, not unlike the advantages of walking on sod versus muddy bare soil after a rain. The roots provide an anchoring effect and improve the soil structure, preventing excessive compaction from grazing animals.

Bottom-line savings from reducing compaction through cover crop use can vary depending on whether it is a wet or dry year, the type of soil, and how much of the field has been compacted. An Iowa State University study cited 10%-20% potential yield loss in unfavorable years from compaction. Of course, compacted soils can be a problem in both dry and wet conditions, the latter both because crop

Cattle grazing a mix of cover crops. Photo by Brett Peshek of Green Cover.

roots may suffer in wet soils and field operations become difficult in poorly drained areas. The Iowa Soybean Association reported average yield losses of 4-6 bushels per acre for corn and 2-3 bushels per acre for soybeans. At 2022 prices, that would be an average yield loss in corn and soybeans costing about $30 per acre. While cover crops are not likely to completely restore compacted soils in the first year of use, ongoing improvements will be seen over a few years of cover cropping, particularly when combined with no-till. Soils can be gradually restored to normal bulk density levels, bringing potential savings on otherwise compacted fields.

Dollars and sense of grazing

Before discussing dollar return from grazing covers, let's get into why grazing of cover crops is a smart strategy. First, consider how all our soils, both prairie- and forest-derived, have evolved with the grazing action of herbivores (buffalo, deer, elk, etc.). Thus, the soil microbial communities present in our soils developed in a time when animal manure, urine, and saliva were frequently deposited. Modern-day studies have shown that the manure, urine, and saliva from cattle stimulate the activity of many soil organisms and seem to contribute to more rapid buildup of soil organic matter.

Aside from soil improvements, I've heard a number of farmers say that adding cattle grazing of cover crops on a row crop farm has provided another income stream to support an additional family member, particularly when combined with converting some less productive ground to pasture so that year-round forage is available. Given how difficult it can be to secure more row crop ground for an additional family member to farm and the high cost of modern farm equipment, grazing cattle or other livestock can be a lower-cost point of entry for family members seeking to start farming.

In terms of dollars, the good news is that grazing cover crops is one of the best ways to boost net income on row crop fields. This is true whether the cattle (or other livestock) are your own or you rent the cover crop ground to a neighbor to graze their animals. Costs of fencing and supplying water will cut into first-year profit if that infrastructure is not already in place, but after those costs are covered, net returns of $50 per acre or more are feasible (based on an analysis in SARE's 2019 report, *Cover Crop Economics*, www.sare.org/cover-crop-economics). Using low-cost electric fencing can keep fencing costs down considerably, and the electric fencing can work well with a managed grazing situation where the cattle are moved regularly to get maximum value from the cover crop forage while minimizing trampling. Portable water tanks are often used with electric fencing to reduce watering costs.

At a farmer panel session on cover crop grazing during the 2019 Iowa Soil Health conference, all three farmers who were grazing cover crops commented on how they had improved net profits by adding grazing. They did note that in a wet spring, the cover crop field could have a muddy appearance from the cattle hooves but, to their surprise, such areas were not compacted and were easy to plant. They were also easier to pull a liquid manure injector or anhydrous ammonia applicator through compared to non-grazed, non-cover-cropped ground.

Tips for cost-effective seeding and management of cover crops

A key aspect of using cover crops in a way that contributes to profitability is, of course, managing them in a cost-effective way. This is particularly true with how the cost of seed and seeding is handled. However, finding the cheapest source of a cover crop seed and broadcasting it thinly with no particular plan can be a penny-wise, pound-foolish approach to saving money.

Experienced cover crop farmers have found that it pays to experiment with different equipment choices and seeding approaches, and indeed most of the bigger users of cover crops will employ more than one approach in any given year to fit the field and time of season. It's not unusual for some farmers to fly cover crop seed onto a few fields, use a grain drill to plant covers on other fields, and then spread some seed with a vertical tillage machine.

Ray Gaesser, a large corn and soybean producer in southwestern Iowa, keeps his cover crop costs down by using a broadcast fertilizer rig he owns and running it right after the combine, before the crop residue gets packed down by rain. The fertilizer rig can broadcast cover crop seed on 100 acres per hour, bringing seeding cost down to about $5 per acre including labor, machinery, and fuel. He also grows most of his own cereal rye, which he valued at $9 per bushel (2021), making the total cost of rye cover crop seeding $14 per acre (broadcasting one bushel of rye per acre). Ray also told me that in some years the harvested cereal rye has been his most profitable cash crop, though the rye yields do vary. Ray's total cost of $14 per acre for seed and seeding is considerably below the national averages of $25 for seed and $12 for seeding, and illustrates the benefit of having a strategy that fits your farm and cropping goals (see more on Ray's cover crop approach in the farmer profiles section).

To summarize, some key steps to keeping cover crop management cost-effective are:

- **Seeding method**. Use a method of seeding that can either cover a lot of acres per hour, or is part of an equipment pass you will be doing anyway, such as vertical tillage or fertilizer application (see Chapter 9 on equipment strategies for more ideas on seeding approach).
- **Type and amount of seed**. Be strategic in selecting the type and amount of cover crop seed. It's important to buy good-quality seed that is weed-free and germination-tested rather than the cheapest seed, but use a modest seeding rate that is sufficient and not excessive for what you need. If you have flat fields and just need to get some living roots from covers in them, you may be able to get by with drilling 30-40 pounds of rye per acre. On sloping fields prone to erosion, a rate of at least 50 pounds per acre is probably needed. If doing grazing of a cover crop, a higher rate such as 80 or more pounds of rye per acre is probably justified to maximize net returns, depending on date of planting. Note that recommended broadcast seeding rates are higher than when using a planter due to lower establishment success rates when broadcasting; depending on the type of seed, a seeding rate 20%-25% higher for broadcasting cover crops compared to using a planter is recommended.
- **Use of mixes**. A strong case can be made for using cover crop mixes of two or more plant species in many situations (see

chapter 6 on cover crop seeding). However, it's also possible to get carried away and add too many expensive seeds into a mix. Again, if grazing where maximum forage value is justified, more costly mixes can pay for themselves. Note that multi-species mixes can be done affordably and can be very beneficial for soil health, pollinators, and/or wildlife. Just be sure to pay attention to seed costs of the individual species in relation to their portion of the mix.

- **Cover crop termination**. Most experienced cover crop farmers consider the cost of terminating a cover crop with herbicides to be something they would have done anyway as part of a spring "burn down" of winter annual weeds. However, the cost of a spray application can potentially be avoided by using a planter with rollers on the back to terminate the cover crop (most cover crop species need to be at the reproductive stage to terminate with rolling). Some novice cover crop users choose a cover crop that winter kills, such as oats or radishes, to avoid having to deal with termination from a cost or labor standpoint; however, this approach sacrifices the benefits of having living roots and soil protection through springtime that comes from winter annual covers. Still, it's a reasonable approach for someone just starting out with cover crops.

When buying cover crop seed, be sure to insist on good-quality seed, which should come with a seed tag that shows germination percentage, weed seed and foreign material content, and is guaranteed not to have noxious weeds. More than one farmer has suffered by buying a truckload of the rock-bottom cheapest cover crop seed they could find, only to find it had very poor germination or excessive weed seed contamination.

Fortunately, there are now many reputable sellers of cover crop seeds with representatives around the country, so do your homework and establish a relationship with a good seed company. If you are interested in growing your own seed, be certain that it's a species that will produce well in your area, that you have access to good cleaning equipment, and most importantly, that the seed is not protected as intellectual property (IP). Most older varieties do not have IP protection, but ask the dealer you obtain the original seed from or check with your state foundation seed office for more information.

Cashing in on incentives

Besides grazing, the other quick way to get a positive net return on cover crops is to take advantage of incentive payments for covers. Many states are now offering cover crop incentive payments, but even if your state doesn't have them, you can certainly request incentive payments through your local USDA Natural Resources Conservation Service (NRCS) office. Incentive payment rates, both federal and state, vary from state to state, but are almost always $30 per acre or more, and are often in the $40-$60 per acre range. If you are a beginning farmer, have organic fields, or fall into certain other categories, you may be able to get even higher rates. And you can also get assistance for setting up grazing systems, such as for fencing or possibly watering systems.

NRCS offers cover crop payment through two main programs: the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). These two programs differ in several ways, but both will provide payments for cover crops. Under EQIP, you can apply to do one or more conservation practices such as cover crops, and typically agree to do that practice for two to three years, receiving annual payments. Under CSP, the payments are typically for five years, but you will usually be asked to develop a conservation plan that includes at least a few conservation approaches. In both programs, you are not guaranteed to be selected for a contract as they select from many applications within the county and state, but generally the majority of applications for cover crops get approved, provided you meet program requirements.

You may also be able to get funding for cover crop planting as part of other special programs, including through projects funded by NRCS, such as cover crop-oriented Regional Conservation Partnership Projects. However, a field or area can only be signed up for one federal cover crop support program at a time. In other words, you can't get both cover crop payments from two government programs for the same field, unless they are for different aspects of cover crop operations, such as support for planting the cover crop versus support for doing late-termination of the cover crop. Some programs may also require that the field to be enrolled has not previously been planted to cover crops.

Another thing to know about state and federal incentive payment programs is that you may need to choose up-front what type of cover crop approach you will use, such as using only winter cereals for covers or using a cover crop mix. You may also be asked to use a particular seeding rate or complete seeding by a certain date. In general, these guidelines are created to help you succeed, and should be reasonable to work with.

Sometimes, offerings of soil carbon payments or regenerative agriculture payments from private sector companies are another way to obtain cover crop support. If the payment is specifically for soil carbon credits, it may be possible to combine that carbon payment with a government incentive payment. Typically, these soil carbon payments are much smaller per acre than government incentive payments, but they are certainly worth considering.

A few states also have discounts on crop insurance for farmers using cover crops. At the time of writing (2022), the states with crop insurance discounts for planting cover crops in the upcoming field season were Iowa, Illinois, and Colorado. The USDA also offered a crop insurance premium payment for past cover crop use as a special initiative in 2021 and 2022 (called the Pandemic Cover Crop Program, which was a temporary, short-term offer).

Insurance for droughts and floods: Winning the weather war

Farming would be easy if the rain came on a predictable schedule and in moderate amounts. How often does that happen? I've heard many farmers say that they feel the weather is getting more unpredictable, with more intense rainstorms, longer dry periods, and bigger temperature fluctuations. Depending on the region they live in, some farmers may find they are facing wetter springs or drier summers, or both. While weather affects all aspects of a farming operation, there's no question that the ability of the soil to soak up rain and withstand drought is critical to the success of most farms.

Improved soil health is increasingly being recognized as a form of crop insurance that can help a farm be resilient in the face of weather extremes. With high rates of rainfall infiltration, a healthy soil will soak up valuable rainfall instead of letting it run off, carrying nutrients and topsoil with it. If that soil also has high organic matter, it can hold that moisture for longer, like a sponge. Residue on the surface can reduce evaporation and keep the soil cooler. All of this helps a crop or pasture get through longer drought periods or deal with higher temperatures.

One of the more remarkable things we've learned about soil health is that cover crops can increase the amount of mycorrhizal fungi in the soil. This type of fungi plays a critical role in providing nutrients and even water to crop roots in return for carbohydrates that are exuded by roots. If the soil is tilled and then dormant with no living roots for seven to eight months a year, then many of the fungi die and the cash crop will suffer, especially during dry periods when roots grow less and access to water and nutrients provided by the fungi is critical.

We're still learning about all the ways that cover crops can help in a drought, but they include:

- The soil stays cooler with cover crop residue on the surface, leading to less crop stress.
- The soil is moister due to less evaporation.
- Rainfall soaks into the soil (infiltrates) better due to cover crop roots and earthworms, leading to less runoff and more water being accumulated in the soil root zone.
- Higher soil organic matter (building gradually over time) acts as a sponge to hold in the moisture; also, the organic matter and microbes build soil structure, increasing soil pore space and thus providing more space for rainfall to be stored in the soil.
- Some cover crops such as rye and radishes can grow deeper than cash crop roots, helping create deep root channels that allow the next year's cash crop to root more deeply, accessing more water; the crop roots will also follow nightcrawler tunnels, rooting deeper into the soil.

- Increased mycorrhizal fungi from cover crops help expand the area that crop roots can access for water and nutrients.
- Cover crops make it easier to do no-till, which is important because soils that aren't being tilled have better macropores and better soil structure, leading to more rain infiltrating and being stored in the soil.

The opposite of drought is, of course, excess moisture. Many farmers using cover crops, especially with no-till, report being able to begin spring field operations, including planting, days ahead of their neighbors in wet springs. A major study on plant crop insurance claims in the extremely wet spring of 2019 found that use of both cover crops and no-till significantly reduced crop insurance claims that year in the six states studied (Illinois, Iowa, Indiana, Missouri, Minnesota, and South Dakota). The study was led by Bruce Sherrick at the University of Illinois. (I was involved as a co-author on that report).

Fears about cover crop soils being colder are often overblown. While it's true that a no-till field with heavy residue will usually stay cooler than a tilled field in spring, with actively growing cover crop roots and a stimulated soil biology, there can be enough respiration from the microbes and cover crop crop roots to warm the soil into the same temperature range as a tilled soil. The soil temperature will vary depending on moisture, soil type, and time of day, but the key is to keep the cover crop alive rather than terminating it too early and creating a wet mat of dead cover residue, which would delay soil warm up.

Fall harvest operations in wet conditions are also reported to be easier in cover-cropped, no-till fields due to better soil structure and drainage. Given the size of modern commodity operations and the need for time-sensitive access to fields, any extra time gained by having cover crops and better soil structure pays significant economic dividends.

What to expect in terms of yield impacts

If you ask farmers who have three or more years of experience using cover crops what kind of yield impacts they are seeing, most will say they are either seeing modest yield increases or, at worst, no difference in yield between fields with covers and fields without. However, there are certainly cases where yield losses have occurred, most often when people are just getting started with cover crops (this is true of both farmers and researchers). Some systems, like cereal rye before soybeans or radishes in the fall before corn the next year, are pretty straightforward and unlikely to create a yield loss. The most common combination that can lead to a minor yield loss is planting corn after cereal rye, especially where the system has not been tried before and the fertility program or termination timing is not properly adjusted.

Six years of National Cover Crop Surveys included yield data from about 500 corn and soybean farmers each year (although the first survey year had yield data from about 200 farmers). This was a survey that I facilitated, and the team I worked on the survey with identified the following conclusions:

- In the first year of cover crop use, yield impacts were normally negligible, though some fields had small increases or losses.
- By the second year of cover crop use, yields started to rise following cover crops, and the degree of positive impact increased with each passing year of cover crop use up through six years or more (which was the longest period asked about).
- For soybeans, use of cover crops increased yields by 3.5% after three years and 5% after five years (data from detailed analysis of 2015 and 2016 crop years, which were relatively normal rainfall years across much of the corn and soybean region). In the drought year of 2012, yield increases following cover crops were over 11%.
- For corn, use of cover crops increased yields by about 1.8% after three years and 3% after five years. In the drought year of 2012, average yield increases following cover crops were just under 10%.
- Even two years of cover crop use provided sizable yield increases of 8%-9% in the drought year of 2012.

Field research studies have in some cases found yield results compatible with the survey information above, and in some cases found no yield impact or minor yield losses. When looking at data from small plot university research, I have noted that often the cover crop growth was reported to be minimal due to very late planting, poor seeding, and/or very early termination. In other cases, researchers handled cover crop termination poorly and crop stands were affected, sometimes leading to a yield hit. Often the planter used in a university trial is not set up specifically for planting into cover crop residue. Also, cereal rye before corn has sometimes caused yield losses, particularly when nitrogen management is not optimized.

One-year, three-year, and five-year payoffs

Evaluating how many years it takes for cover crops to pay off is a little complicated, as identified above. Investing in cover crops needs to be viewed as a multi-year payoff, not unlike liming a field to raise soil pH or installing drain tile, or even buying new field equipment. When applying lime, it may take two to three years before the economic breakeven occurs, and yet it is an accepted practice. The cost of tiling, though one-time, typically takes several years to pay, as does buying new equipment. Considering this, I think that evaluating cover crops solely based on a one-year response is a bit shortsighted. The following list explores what returns may look like after one, three, and five years of cover crop use.

Year One

After one year of cover crop use:

- **Yields**. Yield impact will likely be negligible, except possibly under dry conditions, when a positive response may be seen; a yield loss may occur if rye is used before corn without having a well-designed approach for termination and nitrogen management.
- **Weeds**. If rye is used before soybeans where herbicide-resistant weeds are an issue, herbicide savings of \$10-\$20 per acre may occur (or weeds impact yield), helping offset the cost of cover crop seed.
- **Nutrients**. Fertilizer savings of \$40 per acre or more may be possible if an effective nitrogen-fixing legume is

used before a late-planted crop like sorghum, but otherwise nutrient gains will typically be no more than $10-$15 per acre in the first year, and that assumes fertilizer amounts are slightly adjusted; many farmers stick with the same program in year one of cover crop use, leading to no fertilizer savings initially until soil health starts to improve.

- **Compaction**. Alleviating compaction issues with cover crops may provide some modest returns in yield impacts of a few percent. Whether those yield responses will be seen in year one depends on the amount of cover crop growth, the amount of compaction present, and the weather conditions that occur that year.
- **Systems change**. If cover crops are combined with a move to no-till, the fewer tillage passes and resulting savings in labor, equipment, and fuel can be substantial. Normally, a dip in yield is common in the first year of no-till use, but when combined with cover crop use, that yield dip may be minimized or may not occur. Machinery operations savings from no-till of not having a fall tillage pass such as a fall chisel plow, disking, or vertical tillage tool combined with not needing a field cultivator pass in the spring would save approximately $27 per acre (University of Minnesota machinery cost table, 2022).
- **Grazing**. If the cover crops are grazed where fencing and water are already present, a sizable return of $50 an acre or more may be obtained, assuming adequate growth of the cover crop occurs. If fencing and water need to be installed, that may offset any gains from the value of the cover crop forage.
- **Incentive payments**. If financial incentive payments are obtained, they will typically cover the full cost of cover crop seed and seeding, and often are high enough to also cover termination costs or even provide a positive net return, depending on the amount invested in cover crop seed and the exact rate of payment. Keep in mind that

most incentive payments are multi-year contracts, so as the yields start to rise with each year of cover crop use, the profit picture keeps growing following the incentive payments.

- **Timeliness of field operations**. This is hard to evaluate in dollars per acre, but there can be value in cover crops potentially enabling you to start planting cash crops earlier in the spring and have a wider window to harvest in the fall. These field operation benefits are ones that increase with the number of years cover crops are used, as soil structure improves.

Year Three

After three years of cover crop use:

- **Yields**. Yield impact will generally be positive but the increase will normally be only by a few percent, such as 3%-4% for soybeans or 2%-3% for corn. Yield losses in corn following cereal rye can still occur, but are considerably less likely due to improving soil health and more experience by the grower at this stage. If drought occurs, yield increases following covers are likely to be sizable, probably 10% or more based on 2012 data.
- **Weeds**. Same as after one year.
- **Nutrients**. Fertilizer savings might be up to $40-$80 if a legume is used for nitrogen before a late-planted crop like sorghum or sunflowers; more commonly, fertilizer savings of $10-$20 per acre are likely based on soil health improvements.
- **Compaction**. Alleviating compaction issues with cover crops may provide some modest returns in yield impacts of a few percent, or possibly more in particularly compacted areas of the field.
- **Systems change**. Same as after one year.
- **Grazing**. If the cover crops are grazed where fencing and water are already present, a sizable return of $50

an acre or more may be obtained, assuming adequate growth of the cover crop occurs. If electric fencing and water supply need to be installed, it would offset any gains from the value of the cover crop forage in the first year or two, but by year three, such infrastructure costs are often paid for unless more expensive permanent fencing is installed.

- **Incentive payments**. If financial incentive payments are obtained, they will typically cover the full cost of cover crop seed and seeding, and often are high enough to also cover termination costs or even provide a positive net return, depending on the amount invested in cover crop seed and the exact rate of payment. EQIP contracts for cover crops typically run for three years and CSP contracts for five years.
- **Timeliness of field operations**. Same as after one year.

Year Five

After five years of cover crop use:

- **Yields**. Yield impact will generally be positive and financially significant, such as 5%-6% for soybeans or about 4% for corn. Yield losses following cover crops could still occur in isolated situations if unexpected weather impacts termination and cash crop establishment. If drought occurs, yield increases following covers are likely to be sizable, probably 10% or more based on data from the drought year of 2012.
- **Weeds**. Same as after one year.
- **Nutrients**. Fertilizer savings might be up to $40-$80 if a legume is used for nitrogen before a late-planted crop like sorghum; more commonly, fertilizer savings of $15-$30 per acre are likely based on soil health improvements.
- **Compaction**. Alleviating compaction issues with cover crops may provide some modest returns in yield impacts

of a few percent, or possibly more in particularly compacted areas of the field.

- **Systems change**. Same as after one year.
- **Grazing**. If the cover crops are grazed where fencing and water are already present, a sizable return of $50 an acre or more may be obtained, assuming adequate growth of the cover crop occurs. By year five, any upfront costs for fencing and water supply should have been paid for, allowing for sizable net profit returns over variable costs.
- **Incentive payments**. By year five, EQIP contracts will have expired, as will have some other government payments, with the exception of CSP payments, which normally run for five years for cover crops. However, it may be possible to renew a government contract for cover crops by making enhancements to the practice, such as switching from a winter-kill cover crop like oats to an overwintering one like cereal rye, or switching to a mix instead of single species (check with your relevant program office on program rules).
- **Timeliness of field operations**. After five years of cover cropping, soil health improvements should be noticeable, particularly if the cover crops are combined with no-till, strip-till or other minimal-disturbance management. By this point, better rainfall infiltration and better soil moisture management should be quite apparent, leading to easier spring planting and more days available for fall field operations. The improved timeliness of field access will have a positive net return that could be sizable depending on weather conditions in any given year. By this point, better rainfall infiltration and better soil moisture management should be quite apparent, leading to easier spring planting and more days available for fall field operations. The improved timeliness of field access will have a positive net return that could be sizable depending on weather conditions in any given year.

This outline is a lot of information to digest, but hopefully it helps you identify the impacts that would be most meaningful on your farm. If I were to boil it all down, I'd say that in the first year of cover crop use, you will only have a net profit over the cost of seed and seeding if you obtain incentive payments (which I'd encourage you to take advantage of), if you graze the cover crops, or if you have a particular challenge with herbicide-resistant weeds.

By year three, even without grazing or weed benefits or incentive payments, cover crops should be paying their way in terms of yields, nutrient improvements, and other benefits (at least breaking even or maybe providing a small positive return if seed costs are modest). In a dry year, they can *really* pay. Or if you do factor in incentive payments, grazing, or weeds, you can get a tidy profit from using covers by year three. It's been my experience in talking with hundreds of farmers about cover crops that if they stick with them for at least three years, they are almost always sold on using them long-term because the benefits have become so evident.

By year five, in the vast majority of situations, cover crops should be providing a regular net profit return that will continue indefinitely into the future. The size of the profit return will vary for all the reasons stated above, but at a minimum you should be netting at least \$20-\$30 per acre, and with incentive payments, better weed management, or grazing, that profit return could be \$50-\$100 per acre. On a 1,000-acre row crop farm, that extra \$50,000-\$100,000 in net income could make quite the difference in the success of your operation!

If you want to review additional data on profitability, I recommend the detailed economic case studies of 100 farmers using soil health practices published in 2021 by the Soil Health Institute (do an internet search for "Soil Health Institute economics"). Of the farms studied, no-till was used on 85% of acres and cover crops on 53% of acres, with the average farm size being 1,940 acres. They found that 85% of corn producers using soil health practices and 88% of soybean producers using soil health practices saw net profit increases. The farmers averaged net profit increases of \$52 per acre for corn and \$45 per acre for soybeans. Notably, 97% of the farmers reported improved crop resilience to extreme weather.

CHAPTER 3

Short on time? How to get cover crop seeding done with minimal disruption to your fall schedule

One of the most common concerns expressed by farmers who are not yet using cover crops is that they feel they just don't have time in the fall to get cover crops planted. That's understandable, as most grain farms are busy places in the fall. The good news is that there are numerous ways to start growing cover crops and greening your land without having to sacrifice much or any of your time for harvest and other fall operations. This chapter will look at the pros and cons of the following labor-saving approaches:

- Hiring someone else to do cover crop seeding
- Broadcasting cover crop seed while you are already in the field for other work
- Equipment options that spread seed on a lot of acres in a hurry
- Fitting in some temporary part-time help, maybe from a family member
- Doing cover crop seeding at an earlier time when you are less busy

If you are wondering whether cover crops are too much of a hassle to fit into your busy operation, consider for a moment how you evaluate whether to put lime on a field, or whether to treat soybeans with a fungicide or make an extra herbicide pass. I'm guessing you find ways to get those operations done because you believe they will help your bottom line and, in the case of ag lime, improve the productivity of the field in the long run. In many cases, you are hiring someone to do those operations for you or, if you have a sprayer, are finding time to fit in an extra field pass. The following section will help you figure out how to use cover crops efficiently; but just remember, as discussed in the last chapter on profit, cover crops are an investment that can pay dividends for your operation, just like putting on lime or other soil amendments.

At top: The type of plane you might see performing aerial seeding.
At bottom: Hagie Cover Crop Interseeder preparing to broadcast cover crop seed into standing corn.

Hiring someone else to seed your cover crops

In the 2015-16 National Cover Crop Survey, over 30% of farmers using cover crops reported hiring someone else to do the majority of their seeding. Of those that hired someone to seed covers, about half hired an aerial applicator, about a quarter hired an ag retailer, and another quarter hired a neighbor. All of these are viable options. We'll take a look at each in the following sections.

Aerial seeding

A few years ago at a conference, I was having an extended conversation with an aerial applicator who had gotten into cover crop seeding. I asked him how he felt about flying on cover crops. He responded, "I love it! People living in the country are happy to have me flying seeds on to protect the soil, whereas they don't like it as well when I'm spraying pesticides near their houses!" Since cover crop seeding normally is done in the August-to-October time period when aerial applicators are done with summer pesticide applications, many are happy to have the extra work of cover crop seeding.

If you don't know who the aerial applicators in your area are, you can go the National Agriculture Aviation Association website and use their "find an aerial applicator" link (www.agaviation.org). Many, but not all, aerial applicators will offer cover crop seeding services. However, it does help to hire people who are experienced with cover crop seeding, as the optimum approaches such as flight height often differ from spraying pesticide products. Also, various cover crop seeds spread differently from each other when flown on due to seed density, size, and shape.

Cost of aerial seeding varies depending on how far from your field the applicator has to base their plane to load seed, how much acreage you are spreading (generally more acres and bigger, longer fields cost less per acre), and the amount of seed per acre. Seed that can be broadcast in a wider pattern will also cost less. For example, radish seeds go on at a few pounds per acre, whereas rye may be 50 pounds or more per acre, requiring more trips to load the plane and thus a little more expense. I've typically heard aerial application costs in the range of $12-$15 per acre (plus seed cost), but it varies, and costs may be rising as they are with other services. Chapter 9 on equipment has more information on the success of aerial seeding versus other methods. Aerial application can allow the cover crop to be seeded prior to grain harvest, allowing the cover crops more time to become established. Just be aware that any form of broadcast seeding is more reliant on rain for establishment than using a planter to put the seed into the soil.

Having your ag retailer/fertilizer dealer spread cover crop seed

Another common way to hire out broadcast seeding of cover crops is to work with a local ag retailer. Most often, they will use a fertilizer truck or buggy that can throw the seed in a wide pattern and over many acres in a day. As with airplanes, the cost per acre will depend on distance to your field, size of field, amount of seed to be broadcast, etc. Rates are typically in the same ballpark as aerial application, and sometimes in the lower end of that range, such as $10-$12 per acre, if your field is not too far from the fertilizer dealer. Keep in mind that planes can fly seed on when fields are muddy, but fertilizer rigs can operate when it's too windy to do aerial application. One other limitation of fertilizer rigs for spreading cover crop seed after corn or soybeans is that you have to wait until after harvest in order to avoid tire damage to the crop.

Some ag retailers have started offering the option of using high-clearance rigs to do cover crop seeding into standing corn or soybeans. Using the same rigs that spray herbicides, insecticides, or fungicides, they adapt that equipment with an air seeder and drop tubes to seed the cover crop (see photo on page 51). These rigs can do several hundred acres of seeding per day and because they can go into a field and drive between rows, they allow pre-harvest establishment of cover crops to give seed more time to grow. Costs for seeding are typically in the range of $10-$15 per acre. See chapter 8 for more details on using fertilizer rigs or high-clearance seeders for spreading cover crop seed.

A Salford vertical tillage tool modified with an air seeder for cover crop planting.

Hiring a neighbor to do your cover crop seeding

It might surprise you to know that thousands of farmers have hired a neighbor to do some or all of their cover crop seeding. The advantage of working with a neighbor is often two-fold. First, they will most often use a planter instead of broadcast seeding, which ensures better establishment. Second, they typically have some experience with cover crops and so can give you advice on how to make them work for you. Josh Payne, a young Missouri farmer, has regularly planted cover crops for his neighbors, primarily because he wants to help them get started with covers, but also because it's a way to put some of his equipment and time to use in the fall since he farms fewer acres than some of his neighbors. In the future, I hope more young farmers and some semi-retired farmers will tap into the business opportunity of doing cover crop seeding for other people in their area.

Do the seeding at the same time as another operation

Let's say that, for some reason, you don't want to hire the cover crop seeding done and want to maintain more control over it yourself: what are your options to fit it in without taking a lot of time? Fortunately, there are some viable options, which include doing the seeding at the same time as another operation or using highly efficient seeding techniques (see next section).

The most popular way of seeding cover crops while already in the field for another operation is to broadcast cover crop seed at the

Gandy air seeder attached to corn head, with drop tubes that distribute seed under the corn head.

same time as doing a vertical tillage pass on a field. This normally involves an air seeder that blows the seed through drop tubes in front of the vertical tillage tool (depicted in the photo of a Valmar seeder mounted on a Salford vertical tillage tool on page 51). In other cases, people use a hitch-mounted broadcast spreader for the seed while pulling the vertical tillage tool behind it. This approach works well for cover crop seed that can handle being planted up to an inch deep, like cereal rye, oats, or other small grains. For more shallow-seeded cover crops like radishes, rapeseed, or clover, it may work better to broadcast the seed after the vertical tillage tool.

Other tillage equipment can be similarly modified if the tillage is shallow enough, but be careful not to use a seeder in front of a device that will bury the seed too deep. If a deeper tillage pass is being made, a broadcast pull seeder that is hooked to the back of the tillage instrument can work. (Valmar is one of the companies that offers such pull-type broadcast seeders as well as hitch-mounted ones.)

If you are no-tilling, another option for simple seeding may be to spread cover crop seed while combining. Gandy is one company selling an air seeder that can attach to the combine and blow the cover crop seed down underneath the combine header. That way, the seed can make contact with the soil before all the leaves, stalks, and chaff are blown out the back of the combine. I've had farmers tell me they've had success with combine-mounted seeders, but their popularity has been limited so far.

Yet another approach is to mix cover crop seed in with fertilizer or manure that is being spread in the fall. As described in Chapter 9, cover crop seed can be blended with granular fertilizer, but if so, the seeding should ideally be done right after mixing the two so that the salt action of the fertilizer doesn't start desiccating (drying out) the cover crop seed. The seed may also not be thrown as far as the fertilizer, which can be an issue. Some farmers have added cover crop seed to liquid manure slurries before spreading. Again, the seed should not be mixed in until right before the seeding is to be done. Some adjustments to equipment may be needed, but the nice thing about slurry seeding is that the cover crop seed receives some moisture and fertility to help it become established faster.

At top: A prototype high clearance drill for interseeding cover crops developed at Penn State University. At bottom: The rear of the drill, showing the skip row (blank area with no planter unit) for planting into existing corn with drop nozzles for herbicide and/or liquid fertilizer application.

Various equipment strategies are covered in greater depth in Chapter 9, particularly regarding what pluses and minuses you might expect with each. All of these approaches can work for certain cover crop species but be prepared for some trial and error to get your settings right.

Seeding large quantities of cover crop acres per day

Let's say you prefer to do your cover crop seeding yourself but want to get it done efficiently given your limited number of days for harvest and other field work in the fall. There are ways to cover hundreds of acres per day. One is by using broadcast equipment that can throw the seed far while moving quickly. Ray Gaesser, one of the farmers profiled in this book, uses a fertilizer spreader rig that can do about 500 acres of seeding per day. His goal is to run it immediately after combining a field while the residue is still fluffed up, so the seed has more chance to work its way down to the soil. This works best with a second operator to seed covers following behind the combine operator.

If you already have a high-clearance sprayer, you may find that it can be modified with a kit to add cover crop seeding ability. This will require some time in late summer before harvest to switch the rig over to seeding, but typically the kits can be installed in four to eight hours by those familiar with the process.

Some farmers have found that it's worth adapting their row crop planter to plant covers, if they have a big planter that can do a lot of acres. Others have picked up a wide grain drill, perhaps finding an affordable used one. The upfront cost of a bigger drill is a potential hurdle, but it may quickly pay for itself in labor savings if you are seeding a lot of acres.

Other strategies to keep cover crop seeding from conflicting with fall field work

Chances are that you've already got someone helping you during harvest to drive a grain truck or cart while you run the combine.

If that person is just a temporary helper, such as a retiree, can they stay on an extra week or two after harvest to drill cover crops for you? It's not a complicated task. Or maybe there's a family member who would be willing to run a grain drill or spreader with seed right behind the combine. You'll be in the field anyway and so can provide some oversight, and again, it's not necessarily a complicated task to pull a drill or spreader around the field.

Here's a whole other option: seed the cover crops before harvest. In the National Cover Crop Survey, about a third of the farmers reported doing at least some of their primary cover crop seeding before they harvested the cash crop. Most often this looks like spreading seed into crops like standing corn, soybeans, cotton, or sorghum once the crop has started to turn color, such as in late August or early September. Planting the seed on the field early allows the cover crops to get a head start before harvest, while also allowing you to get that project out of the way before you start harvest. Of course, the broadcast seeding is rain dependent, and that's why some farmers prefer to drill the seed for greater certainty of establishment. See chapter 6 for more details on the timing of cover crop seeding.

One of the newest trends with cover crops is to seed them even earlier–in June instead of late summer. This works better with corn than soybeans, and I don't think it's been tried much yet with other crops, other than the old practice of over-seeding a legume into wheat. Some people have used broadcast spreaders, maybe broadcasting fertilizer and cover crop seed into corn at the same time during June. Others have used high-clearance grain drills made specifically for interseeding that have higher success rates in planting. Notably, the "InterSeeder" drill made by InterSeeder Technologies can spray a post-emergence herbicide and/or a liquid fertilizer at the same time as drilling a cover crop in between corn rows. Thus, three field operations can be combined into one.

My own feeling is that June interseeding into corn probably works better in the northern half of the Corn Belt than the southern half, and better where there is more rain, because hot and dry conditions make it tough for a June-planted cover crop to compete with corn all the way to harvest. However, I've seen a number of fields where it has worked reasonably well. As people continue to experiment with which species, varieties, and techniques work best for cover crop interseeding, I expect additional solutions will be found which will broaden the approach to more geographic areas.

CHAPTER 4

Cover crops will build your soil health: Why that matters

You've probably been seeing articles about soil health in the farm media or heard it talked about on farm radio. You may have attended a field tour or farmer meeting where soil health was discussed. It's almost impossible to avoid hearing about soil health, and when the discussion is about soil health, cover crops are sure to be part of the conversation. Why is this such a hot topic now?

Sometimes I hear people say, "There's nothing new about cover crops." It's certainly true that cover crops have been used for centuries. In fact, before the rise of synthetic fertilizers following World War II, there were really only two common ways to replace the soil nutrients removed by crops: either apply manure to the field or grow a green manure legume crop in the rotation, like alfalfa for hay or a clover cover crop. In the Dust Bowl era, cover crops were widely promoted to address soil erosion, which remains a strong reason to use cover crops to this day.

However, we now know through a much greater understanding of soil biology that cover crops do far more than simply benefit soil fertility or prevent erosion–when we provide living roots to the soil for a greater portion of the year, the soil ecosystem provides all kinds of other benefits to us. In addition to our much greater understanding of soil biology, another thing that has changed in recent years is the number of cover crop species available to grow and improved management techniques. Cover crops are more diverse and the ways of using them are much more advanced than they were decades ago, when the only choice seemed to be to plow them into the soil.

We now have plant species available to use as covers that were not used in the past for that purpose, like radishes or balansa clover in the fall and sunn hemp in the summer. Instead of plowing cover crops to terminate them, we can use herbicides or roller crimpers, or use winter-kill cover crops like the previously mentioned radish-

Sunn hemp is a tall and vigorous summer legume cover crop.

es. We also have much better planters for planting into cover crop residue. The use of no-till, strip-till, or other minimum-till techniques is more viable than ever before due to modern herbicides, precision-farming, GPS, and other management techniques, and these conservation tillage approaches work very well in combination with cover crops.

All of these factors have played a role in bringing cover crops back to the forefront, and the fact that cover crops have been part of agriculture for so many centuries should certainly be one additional reason to consider using them once again. More importantly, our new understanding of soil biology is worth exploring further when considering whether cover crops are right for your situation.

The Natural Resources Conservation Service (NRCS) has identified four main principles for soil health:

1. Keep the soil covered as much as possible
2. Disturb the soil as little as possible
3. Keep plants growing throughout the year to feed the soil
4. Diversify crop rotations as much as possible, including with cover crops

Cover crops contribute to all four of these soil health goals, but they are the only way to achieve the third goal of feeding the soil year-round when growing annual commodity crops. The living roots provided by cover crops play a huge role in maintaining and building soil health. This chapter will take a deeper look at the following aspects of soil health related to cover crops:

- Managing soil nutrients
- Building soil organic matter and strengthening the soil
- Keeping the soil covered
- Managing soil moisture
- Contributing to biodiversity

Managing soil nutrients

It used to be common practice to look at soil fertility as an input-output sort of model, particularly for nitrogen: put on 150 pounds of nitrogen fertilizer per acre and get 150 bushels of corn; add another 30 pounds of nitrogen and get another 30 bushels to the acre. In fact, in many areas, farmers were encouraged simply to set a yield goal–say 220 bushels an acre–and fertilize according to that number, putting aside considerations such as soil organic matter, texture class, profile, and weather.

We now understand that a diverse community of soil organisms plays an invaluable role in plant nutrition, and particularly in creating a healthy soil. This role is a complex one; it has impacts in relation to weather conditions and both short-term and long-term soil changes that affect how soil nutrients are cycled and whether they are available in the root zone to the cash crop being grown.

The easiest part of the soil biology to observe and understand is the action of earthworms. As earthworms tunnel, they leave nutrient-rich castings behind that attract both microbes and crop roots that are seeking nutrients. The tunnels also move rainfall deeper into the soil and allow roots to grow deeper, tapping into nutrients in lower parts of the soil profile (see a more in-depth discussion on earthworms in Chapter 5).

While earthworms and their tunneling are easily visible, the unseen microbial world of soil organisms has just as big of an impact on soil fertility for crop growth. Mycorrhizal fungi are a group of beneficial soil organisms that play a significant role in helping crop roots access more soil nutrients. The fungal hyphae–long, branching structures–are particularly beneficial for crops because they create better access to phosphorus in the soil, and they can also provide other nutrients to crop roots in return for the sugars and other carbohydrates the crop roots exude.

Other soil organisms also impact nutrient availability in the soil. In the short-term, as they break down the roots and residue of previous plants in the field, they release a certain amount of nutrients to the following crop. Farmers have noted that healthier soils seem to recycle crop residues more quickly than overly disturbed, worn-out soils. In the long term, these soil microbes become part of the fabric of soil organic matter that builds soil aggregates and gives soil improved structure. The more expansive root growth of the crops is critical to accessing as much soil fertility as possible. Thus, the hidden, microscopic life in soil is helping corn grow green and tall as much as

Balansa clover (pinkish white flowers) mixed with crimson clover – both are cool season clovers typically planted in the fall.

earthworms do. (Additional details on soil fungi and other microbes are in Chapter 5.)

Legume cover crops

Legumes are believed to have the longest history of use as cover crops, in large part because of their ability to fix nitrogen, and thus provide a key soil nutrient to other crops. Before the advent of modern synthetic nitrogen fertilizer manufacturing, application of livestock manure to fields and green manuring with legume cover crops were the most common methods of adding nitrogen to crop fields. The benefits of green manuring with legumes dates back at least to the ancient Romans, and early American farmers such as George Washington and Thomas Jefferson recommended use of green manures to their fellow farmers (during their era of farming, the more common practice was to farm the land with corn, tobacco, or small grains until the natural soil fertility was depleted and then move farther west, rather than make use of soil-improving legumes).

Today, there are a large number of legumes available to use as cover crops, many of which are detailed in Chapter 7. Rather than going through the pros and cons of each legume species in this section, I'll focus on the role of legumes in soil health and fertility. Of course, the nitrogen-fixing ability of legumes is the trait that stands out most, and some legume species can produce a remarkable amount of nitrogen if given sufficient time to grow. Some of the top nitrogen-fixing cover crops include:

- Winter annuals such as crimson clover, balansa clover, hairy vetch, and winter pea
- Summer annuals such as cowpeas and sunn hemp
- Biennials such as yellow sweet clover and white sweet clover
- Perennials such as red clover and alfalfa

Under ideal conditions, many of these legumes can fix 100 or more pounds of nitrogen per acre, greatly reducing or eliminating the need for nitrogen fertilizer. This makes legume cover crops popular for everyone from small gardeners to big farmers, and particularly for organic farmers who are limited in their nitrogen options.

Legumes' contributions to soil health go beyond just nitrogen fixation, however. Legumes have a low carbon-to-nitrogen (C:N) ratio, so they are quickly recycled by soil microbes into the organic fraction of the soil. Whether tilled in or allowed to be incorporated into the soil by earthworms and soil microbes, legumes are a good tool for building soil organic matter, particularly when used with higher-biomass cover crops such as winter cereals or fast-growing summer grasses (e.g., sorghum-sudan or pearl millet). Use of legumes as cover crops also adds to the biodiversity of crop rotations, and many legumes provide an extended flowering period that is conducive to attracting pollinators and other beneficial insects.

Scavenging nutrients

No discussion of cover crops and nutrients is complete without mentioning the ability of cover crops to take up or scavenge leftover soil nutrients at the end of a growing season. It has been documented that nitrogen in particular is very mobile in the soil, and much of the available nitrogen left in the root zone after harvesting crops like corn or cotton is prone to leach away, especially in higher-rainfall areas. Some cover crops appear to be better than others at taking up the leftover nitrogen and other nutrients, but any cover crop is better than none in this regard.

Radishes in particular have been cited for their ability to grow quickly (if planted in early fall) and root deeply enough to grab leftover nitrogen and other nutrients. The question not entirely answered by research is: What happens to the nitrogen that radishes take up in the fall? With exact timing dependent upon latitude and weather, radish roots and top growth decompose as winter nears its end. At that point, the nitrogen held in the radish tubers, roots, and leaves is released. Some may go off into the atmosphere, and some is undoubtedly recycled by soil organisms, but conflicting information has come out of research on radishes and their impact on nitrogen cycling. There is concern by researchers that radishes grown alone may release the nitrogen more quickly in spring than it can be used by a crop such as corn. To reduce the loss of nitrogen from radishes, I recommend using them with other cover crops in mixes, particularly with a winter cereal crop that can help pick up and hold nitrogen for longer in the spring.

Cereal rye residues, on the other hand, may hold nitrogen for too long. Rye is the most studied cover crop in terms of nitrogen impact, helped along by many years of work by scientists such as Tom Kasper in Iowa and others. When cereal rye is allowed to grow past flowering, it ends up with a relatively high C:N ratio. This makes it more difficult for soil microbes to break down the rye residue, leading to a longer recycling time for the nutrients, including nitrogen, from the rye into the soil. Studies to date have indicated that the majority of nitrogen available from post-anthesis (post-flowering) cereal rye may not be available in the soil until late summer, which is past the time when corn or other summer crops could most benefit from that recycled nitrogen.

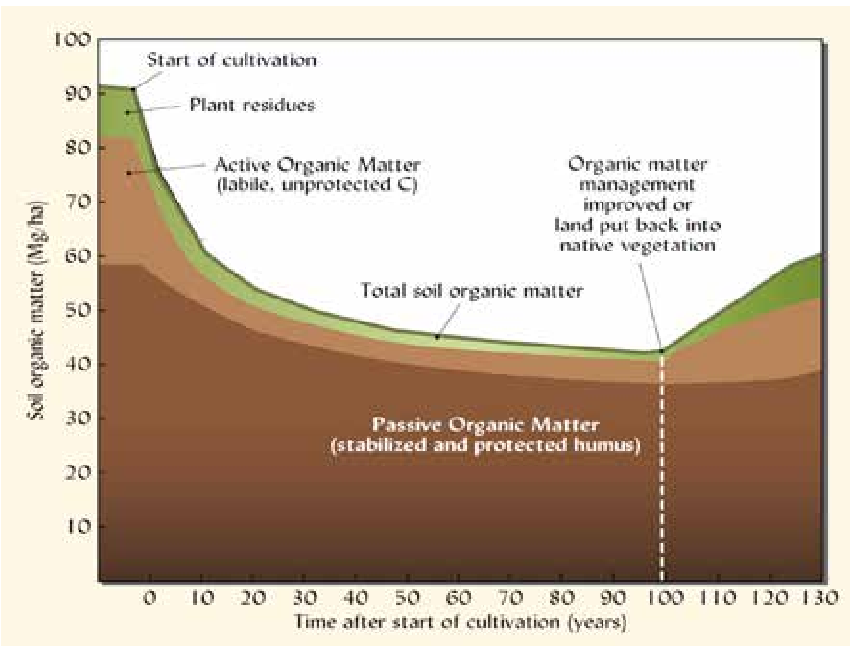
There are two approaches to speeding up the bioavailability of nitrogen from rye. One is to terminate the rye earlier, while it is still vegetative (before seed heads appear). At this stage, the rye has a C:N ratio more in line with what soil microbes need, speeding up their decomposition of rye residue. Another approach is to complement cereal rye with other cover crops that have a lower C:N ratio, particularly legumes. Hairy vetch may have the best ability to grow vigorously when mixed with rye, but other legumes can work if the rye population is kept thin enough, allowing the legume a chance to grow effectively. If a sufficient amount of legume biomass exists alongside the rye at termination, then the C:N ratio will be more favorable and rye residue will break down more quickly.

Building soil organic matter and strengthening the soil

Ask any farmer about soil organic matter and they will tell you it’s important, but many are less familiar with how to build organic matter or what exactly it can do to improve profitability. The figure on the next page, created by Ray Weil for his popular textbook *The Nature and Property of Soils*, depicts at a glance what has happened to our soil organic matter on farmed fields, and how it can be rebuilt. It shows some of the different fractions of soil carbon that make up soil organic matter and how, on average, we’ve lost about half of the soil organic matter we had from the time agriculture by European colonists started in the U.S. When I first became aware of this fact several years ago, I can't say I was surprised, but it was still a dispiriting moment. However, the optimist in me looks at the graph below and sees the opportunity to rebuild our soil organic matter–we know the soils can hold a lot more carbon than they are now!

Why is it important to rebuild soil organic matter? To me, it's like having a set of well-maintained and powerful tractors to use in the farming operation; everything else becomes easier if there is plenty of reliable power to pull planters and grain carts and do other farm work. Or you could equate it to having a good supply of electric power in the farm shop – many of the other tasks in that farm shop get easier with reliable electric power.

How does organic matter power our fields? It's been described as the sponge, the reservoir, the glue, and the storehouse of nutrients. If you've been to a recent soil health meeting, you've probably heard it said that if you could boost your soil organic matter by just one per-



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centage point, such as from 2% to 3%, your field could store approximately 27,000 additional gallons of water per acre. However, it's not simply a matter of storing that water; it's also a matter of holding on to it for longer, rather than it quickly draining out of the root zone. The organic matter, in combination with clay soil particles, creates more area for surface tension to hold the water in place. This keeps the water available for crops to use for a longer period of time.

The exact contribution of increased organic matter to crop nutrition is harder to pin down, but without question, a higher-organic-matter soil has a higher level of inherent fertility, leading to potential savings on fertilizer each year. Organic matter, particularly the active carbon fraction, is positively correlated with soil health–so the more active carbon a soil contains, the healthier the soil is and the more conducive it is to crop growth.

Increased soil carbon also allows soil organisms to generate more glomalin, which is the glue that holds soil particles together and builds better soil aggregates. These aggregates are the building blocks of soil structure, creating surface area for microbes to live on. Better soil aggregation also provides more pore spaces for air and water in the soil and gives the soil strength to resist compaction from field operations.

Research at Ohio State University over a several-year period showed that compaction caused by a 20-ton grain cart was more effectively remedied by cover crops than by subsoiling. While subsoiling equipment can provide some temporary relief to compaction, clay soils often swell back together quickly where the subsoiling knife or shank has traveled. Earthworms stimulated by cover crops and cover crop roots, along with gradual soil organic matter increases, do a better job of not only repairing compaction but also reducing the soil's susceptibility to future compaction.

Keeping the soil covered

Cover cropping, if done in combination with no-till or very minimal tillage, can do a great job of keeping the soil covered. Maintaining soil coverage year-round is one of the core NRCS soil health principles. Living cover crops, if planted in a dense stand, are particularly effective at covering the soil while alive, of course; but what about after they are terminated? Even then, the residue left behind by cover crops can persist for several weeks, and sometimes for months, depending on the C:N ratio of the cover crop residue and how biologically active the soil is in breaking down surface residue.

Cereal rye in particular is noted for providing a beneficial mat of residue after termination. The rye can be made into a surface mat with a roller crimper or simply by being knocked down by a cash crop planter. The rye mulch, if thick enough, can do a great job of reducing weed seed germination and emergence.

Soil cover is helpful in ways beyond just weed suppression. Protection against both water and wind erosion is one key benefit. Water erosion starts when a raindrop splashes against the ground and dislodges soil particles; living cover crop leaves and stems or residue intercept raindrops and prevent soil from being dislodged. Cover crop roots also anchor the soil and reduce water and wind erosion, and the residue traps windblown soil particles. Overall, cover crops have been documented to reduce erosion by 90% or more.

Soil temperature is also impacted by the cover of plants and residue. Both living cover crops and dried residue after a cover crop is terminated can keep the soil cooler, which is helpful since the heat of early summer sunshine tends to elevate soil temperatures until the cash crop can completely shade the soil. In fact, on a hot June day, temperatures of bare soil between crop rows may be 20°F-30°F higher than soil under a cover crop residue blanket. Soil microbes function best at temperatures in the 70s, so hotter soil temperatures reduce soil functioning as well as stress crop roots and accelerate soil evaporation of needed moisture.

Some farmers worry that cover crops and no-till practices may lead to colder, wetter soils that delay planting, but it's important to remember that a living cover crop creates significant biological activity and soil conditions that are often no cooler than a conventional field in early spring. Even with a winter-kill cover crop in a no-till operation, the soil temperature may be relatively unaffected.

Cereal rye residue providing a residue blanket that reduces loss of soil moisture.

Ryan Stockwell, who farms in north-central Wisconsin and works for Indigo Ag, did a comparison of soil temperatures at 4-inch depth on a tilled field, a no-till field with winter-killed cover crops (no live cover crops), and his lawn in 2014 and got the following results:

Week	Date/Time	Lawn (average temp. in °F from 4 samples)	No-till with winter-killed cover crop	Fall-tilled
1	April 22 @ 11:15am	42.85	44.45	45.75
2	May 2 @ 7:30am	41.98	41.4	40.93
3	May 6 @ 8:50am	45.13	44.88	43.43
4	May 13 @ 8:35am	54.2	53.68	53.07
4b	May 13 @ 7:10pm	53.03	52.96	52.63
5	May 19 @ 10:50am	51.83	52.58	52.45
6	May 26 @ 11:40am	61.97	68.45	69.17

Conventional thinking would be that the fall tilled soil would always be the warmest, but in the case above, there was generally no advantage compared to a winter kill cover crop in no-till. Interestingly, the sodded lawn was often about the same temp, although it was slightly cooler on the very first reading of the spring and kept the soil cooler at the end of May when air temps were starting to really rise. Keep in mind different depths in the soil will respond differently, and the top inch will heat up faster than the four-inch depth that Ryan tested.

Managing soil moisture

Soil staying excessively dry or excessively wet (anaerobic) for prolonged periods leads not only to dead or dormant soil organisms, but also improper functioning of crop roots. In a very dry soil, crop roots simply won't continue growing. I've dug up crop roots in sandy soils that turned and grew at right angles when they hit a dry zone of the soil. With limited roots and little access to soil moisture, the top part of the plant inevitably wilts and grows poorly, if at all. A field of corn or cotton that's been hammered by drought is not a pretty sight.

A water-logged soil can be just as problematic for crops and even more likely to lead to premature crop death. Without access to air in the soil, crop roots stop functioning and plant death follows. Where conditions are not totally saturated but still too wet, root growth is impaired. Crop diseases become an issue as well, not only because some plant pathogens thrive in high moisture, but also because the crop is weakened and more easily invaded by the pathogens.

None of this is news to any farmer, so the question is how to build soil health to the point where moisture extremes are moderated by the buffering ability of a resilient soil. Drainage tile can certainly help with excess moisture on some soil types. Developing better internal soil drainage through improved macropores and soil structure can also be helpful for both wet and dry conditions. In a tilled soil, heavy rainfall can quickly seal up the soil surface, leading much of the rain to run off of fields or "pond" in low spots of fields. By minimizing disturbance and maximizing creation of macropores from earthworms and root channels, water moves not only more easily from the surface into the soil profile, but also throughout the profile, leading to a greater volume of the profile storing moisture.

If we compare soil structure to human transportation infrastructure, macropores are like the interstate highways of soil that move large volumes of resources (water) and allow long-distance travel (propagation of roots), but soil aggregates are like all the neighborhood blocks with side streets that allow people to travel to their homes, stores, and businesses. In the case of the rootzone, when well-aggregated soil provides plenty of side streets in terms of where water and roots can travel, the roots can access more moisture and more nutrients. The well-structured soil also holds up better to field traffic, allowing wider windows for planting and harvest and reducing the likelihood of compaction. Avoiding compaction is absolutely critical to prevent conditions in which root growth is restricted and there is limited soil volume to hold rainfall.

Cover crops build soil structure by supporting mycorrhizal fungi that in turn form glomalin. The glomalin serves as the glue to build soil structure, similar to mortar helping build a cement block foundation.

A cover crop mix of hairy vetch, crimson clover, and cereal rye in spring.

As mentioned above, minimizing soil disturbance while using cover crops is key to taking maximum advantage of the benefits they provide, including building soil structure and organic matter. There are many other ways that cover crops improve soil moisture. To summarize the key ways that cover crops help in a dry year:

- **Residue blanket**. Cover crop residue left after spring termination provides a residue blanket that reduces evaporation from the soil.
- **Rooting depth**. Deep-rooted cover crops (winter cereals, annual ryegrass, radishes, sunflowers, etc.) open up a deeper volume of soil for crop roots to access, since the crop roots often follow previous root channels. The extra 6-12 inches of rooting depth a cover crop may foster can make a big difference in a dry year. Some cover crops can also improve growth into restricted root zones in the soil, whether those zones are from compaction or natural soil conditions.
- **Efficient moisture extraction**. Mycorrhizal fungi occur at higher levels in cover-cropped soils, particularly those with minimal disturbance, and the fungi effectively expand the soil volume that can be tapped for soil moisture as well as nutrients.
- **Rainfall infiltration**. Stimulation of earthworm tunnels and creation of root channels moves rainfall from the surface into and throughout the rootzone. This is particularly valuable during intense rainstorms when much of the rainfall might otherwise run off.
- **Water storage in the rootzone**. By building soil structure and soil organic matter and reducing compaction, cover crops create a soil with less bulk density and greater capacity to hold water.
- **Healthier plants**. Healthier soil leads to healthier plants that grow more vigorously. Crops benefit from less pressure from some pests and a more continual supply of nutrients, allowing them to grow more vigorously. In turn, they produce more root growth early in the cropping season, growing roots deep down before weather turns dry and soil moisture becomes deficient in the upper soil profile.

When cover crop use first started taking off in the U.S., there were some scientists and producers who lacked experience with covers and just assumed that cover crops would dry out the soil too much. After all, a cover crop does transpire moisture out of the soil. Indeed, in a dry spring a cover crop should be terminated early to avoid drying out the soil too much.

However, farmer experience and subsequent research have shown that multi-year use of cover crops, particularly with no-till, generally leads to the improvements outlined on the previous page. Some of these changes happen in the first year of cover crop use, such as increased earthworms and mycorrhizal fungi, a residue blanket, and better rooting potential of the cash crop following a deep-rooted cover crop. For example, during the major drought of 2012, even first-year cover crop users reported significant yield savings. Hopefully, future crop insurance policies will reflect the benefits that cover crops provide in reducing yield losses during weather extremes, particularly dry weather.

Contributing to biodiversity

Why is biodiversity important for a successful cropping system? After all, when we look at a field of corn, cotton, soybeans, or wheat, isn't it all just one species growing out there?

One oft-cited phrase from Aristotle is that "nature abhors a vacuum." Where only one species of plant is growing, such as soybeans, nature wants to add many other plant species in the form of weeds. Of course, natural plant communities are normally highly diverse, whether we think of prairies or forests. A few years ago, I was part of a group touring a native tall-grass prairie in central Missouri. The prairie biologist leading our tour identified over 50 species of plants growing in the prairie, illustrating the direction nature tends to go with plant diversity.

Cultivating more plant biodiversity in our cropping system doesn't mean we have to grow multiple cash crops interplanted. We can increase biodiversity by adding additional cash crops to the rotation, such as adding a small grain or alfalfa into a corn-soybean rotation. Cover crops are a great way to add plant biodiversity, because they not only lead to more than one plant species growing in a field during the course of a year, but also because cover crop mixes can be used with multiple plant species.

Fully appreciating the benefits of biodiversity for farming requires looking beyond only the plants in a field. We can consider other changes in species populations we can see, such as greater plant diversity contributing to greater diversity of songbirds and other wildlife, and greater diversity of insects, including pollinators and other beneficial insects. We can also consider the species we can't see – microbes like soil mycorrhizal fungi and beneficial bacteria – which are doing so much work in the soil that benefits our farm goals.

The more diverse the soil microbial community is, the more resilient it is in the face of disruption from weather extremes. A diverse, healthy soil ecosystem does a better job of recycling soil nutrients and building organic matter (see more on this in the next chapter). Crop roots are more likely to grow well in a healthy soil ecosystem, leading to healthier crop plants overall.

Put into simple terms, think of a community slammed by a tornado: would that community rebuild faster with a diverse set of people with wide-ranging expertise, such as plumbers, electricians, carpenters, architects, engineers, finance and medical experts, etc., or would it rebuild faster with only one type of person with one skill set? If we have an overly disturbed soil with no living cover and reduced soil diversity, often favoring short-lived bacteria, that soil will not be resilient and will not contribute to healthy crop growth. If we pour on fertilizers, we can partly and temporarily overcome these deficiencies, but we may find ourselves needing to add other external inputs like pesticides and fungicides to the system as well, trying to rebalance the system with chemical inputs rather than benefitting from a biologically balanced system.

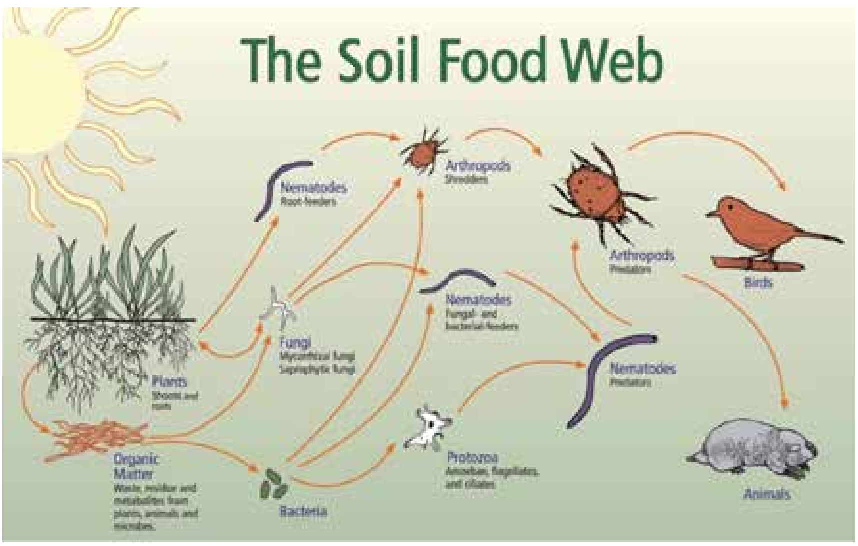
CHAPTER 5

Earthworms, soil fungi, and microbes that boost your soil performance

The soil ecosystem, teeming with life

Healthy soil literally teems with life–much of it microscopic, but all of it interconnected. A single teaspoon of healthy soil can contain more organisms than there are people on our entire planet: billions of bacteria, millions of fungi, hundreds of thousands of protozoa, and thousands of other tiny creatures. Like in the ocean, where we know plankton are eaten by shrimp which are eaten by small fish, then small fish are in turn eaten by progressively larger fish and marine mammals, there's a whole complex food web in a healthy soil. This food web, depicted below, is converting plant residues into soil organic matter, exchanging nutrients with plant roots, building soil structure, and contributing to soil resiliency.

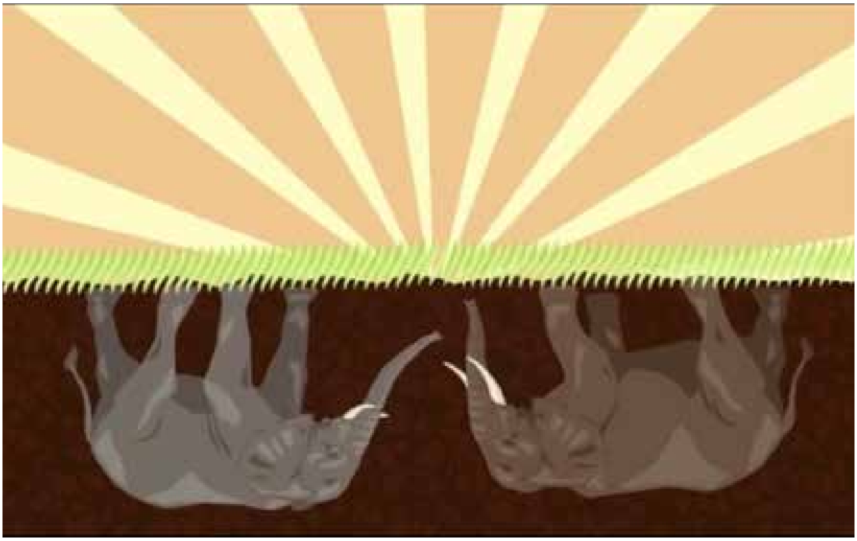
A healthy soil is highly dependent on living roots being present year-



This illustration from the USDA Natural Resources Conservation Service depicts in a simplified way the highly diverse food web that exists in the soil, with interactions between plant roots and a variety of soil organisms.

round, not unlike a forest or prairie. Soil organisms have evolved in the presence of diverse, year-round plant roots, so when there is only a single species of plant in the ground for just part of the year followed by months of bare soil, the system quickly gets out-of-whack, and soil diversity and health quickly decline.

To help represent the amount of food needed to sustain the billions of microbes, insects, and earthworms in a healthy soil, Jerry Hatfield (a now-retired USDA Agricultural Research Service scientist and administrator) has often shared with audiences that on every acre of land, we're basically trying to keep two African elephants alive, in terms of the weight equivalence of all the soil organisms. That takes a lot of plant food, and a lot of roots!



Feeding all the soil organisms in one acre of healthy soil is like feeding two African elephants. llustration by Chelsea Myers, courtesy of the Soil Health Institute.

Earthworms

You hear a lot about earthworms in connection with soil health. An increase in number of earthworms is one of the first changes many farmers notice within a year or two of beginning to use cover crops.

Beyond being a visible indicator of soil health, earthworms play a valuable role in making soils healthier. They improve rainfall infiltration, help break down plant residue, recycle nutrients, support improved crop root growth, and stimulate soil biology.

There are over one hundred species of earthworms native to the U.S. (some scientists say there are up to 300 species). Earthworms in crop fields can be of several species, both native and non-native, and are generally grouped into three types. The type of earthworm found in the top several inches of soil is called endogeic worms and are characterized by tunneling more horizontally than vertically. Right at the surface, if there's enough leaf litter, there may also be epigeic worms. These are the type of small red worm normally used in compost bins, but they are often absent from crop fields. The most well-known type of earthworms found in crop fields are deep-tunneling nightcrawlers, a type of anecic worm, which tend to tunnel vertically and can create tunnels several feet long. Unlike other earthworms, they will actually pull leaves and other decomposing plant material down into the soil from the surface, speeding up the decomposition process of crop residue. While nightcrawlers came from Europe and are not native to the U.S., they have become ubiquitous in most U.S. crop fields. If a field is sandy or particularly dry it may be difficult to find earthworms near the surface, but mustard powder added to water can be used to temporarily bring worms to the surface and identify what is in that section of soil (check out online videos that show how to do this).

One of the most dramatic impacts of earthworms in undisturbed soils is that they increase rainfall infiltration. Their tunnels can allow rainwater to quickly move into the soil, and the overall network of earthworm channels spreads and stores the water throughout the rootzone. This network of tunnels also facilitates better root growth by crops. The tunnels are lined with nutrient-dense castings that act as fertilizer for the crop roots, promoting growth. Earthworm activity also plays a big role in overall soil biology, as earthworm castings become food for many microbes, and the earthworms themselves feed on fungi as well as decomposing plant and animal matter. If a field or pasture is grazed, earthworms can help break down and recycle nutrients from manure into the soil. The castings from earth-

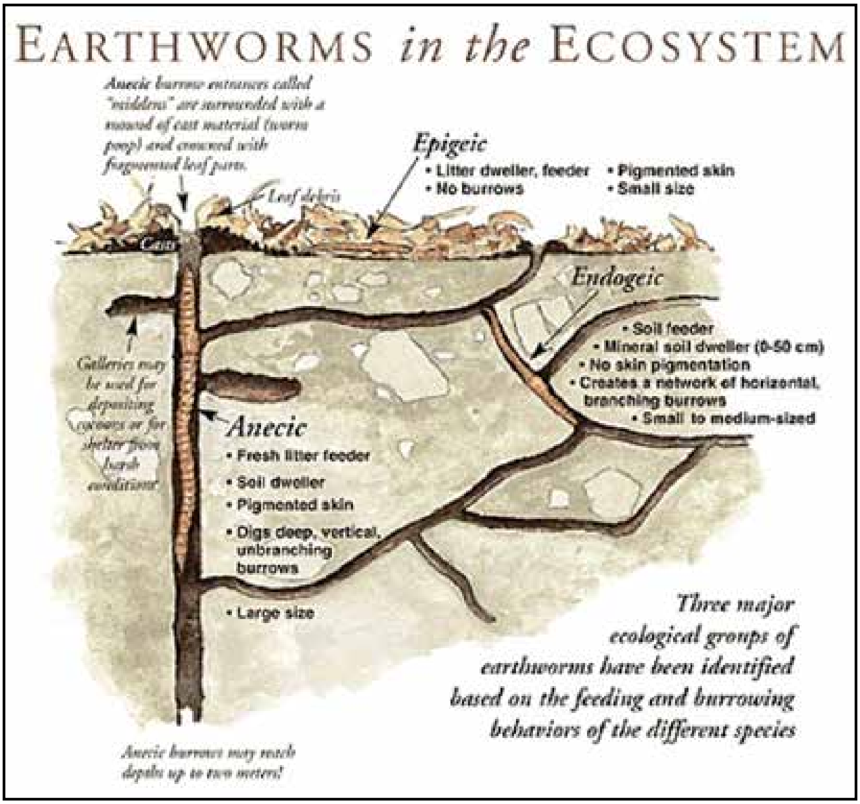


Illustration depicting different types of earthworms by Rick Kollath, used with permission.

worms also play a role in helping build better soil structure, which is a key aspect of soil health.

Nightcrawlers can live in the soil for a few years and their deep tunnels can be long-lasting. In fact, they can do a better job of breaking up compacted soil than expensive subsoiling equipment dragged through a field. Nightcrawlers can also get big, sometimes a foot or more in length, though that's nothing compared to the Oregon Giant Earthworm that is native to the Willamette Valley of western Oregon, which can grow up to three feet long!

Worms breathe through their skin, a diffusion process that requires them to live in moist soil. If the soil is too dry, they will burrow deeper. If the soil is too wet, such as after a heavy rain, they need to come to the surface to breathe, which is why you see so many earthworms on sidewalks or driveways after a big rainfall.

Farmers who are monitoring their soil health often like to take a shovel with them, digging in a few spots to sample soil structure and earthworm activity. Increased numbers of earthworms can appear quickly after cover crop use starts, even after the first year of cover crop use. Decomposing cover crop roots and residue provide a food source for earthworms that sustains them and helps their population increase. According to USDA-NRCS, earthworms can decompose up to two tons of dry plant material a year, improving soil organic matter in the process.

Soil fungi

There are many types of soil fungi, and in undisturbed soils some fungi can cover extensive areas. One of the more common examples of this is fairy toadstool rings, which can pop up from the perimeter of certain types of soil fungi. In my own yard, I've seen these cover an area 20-30 feet across. Another indication of their presence can be the darker green from nitrogen release around the perimeter of the fungal mass.

Among the many types of soil fungi, the most beneficial to crop plants and many other types of plants are mycorrhizal fungi. There are a number of different kinds of mycorrhizal fungi. Some are mainly associated with trees, but arbuscular mycorrhizal fungi (AMF) are found associated with 80%-90% of all plants, including herbaceous and woody species.

Arbuscular mycorrhizal fungi are rather amazing organisms that are hard to fully visualize. A simple description is that the fungal hyphae form a network of filaments throughout the rootzone, with connection points to plant roots. Part of the mycorrhizae will grow into the cells of plant roots, where metabolic exchanges of nutrients can take place. The structures inside the cells are called arbuscules. The tiny filaments of the fungi can extensively infiltrate the soil volume. To get an idea of how many filaments there can be in a small area, imagine over one mile's worth of fungal hyphae (mycelium) in a small

At top: Photo of "fairy ring" mushrooms growing from a single underground fungi. At bottom: soil fungi is indicated by darker green grass caused by nutrient release as the fungi decomposes underground plant material.

pot of healthy soil. The network can be quite intricate and interwoven, but a simple visualization is provided below, illustrating how AMF can help roots access a greater volume of the soil for nutrients and water.

AMF, which will simply be referred to as mycorrhizae for the rest of this discussion, provide many significant benefits to crop plants and soil health, including making more nutrients available to the plant. Mycorrhizae are able to release chemicals into the soil that help

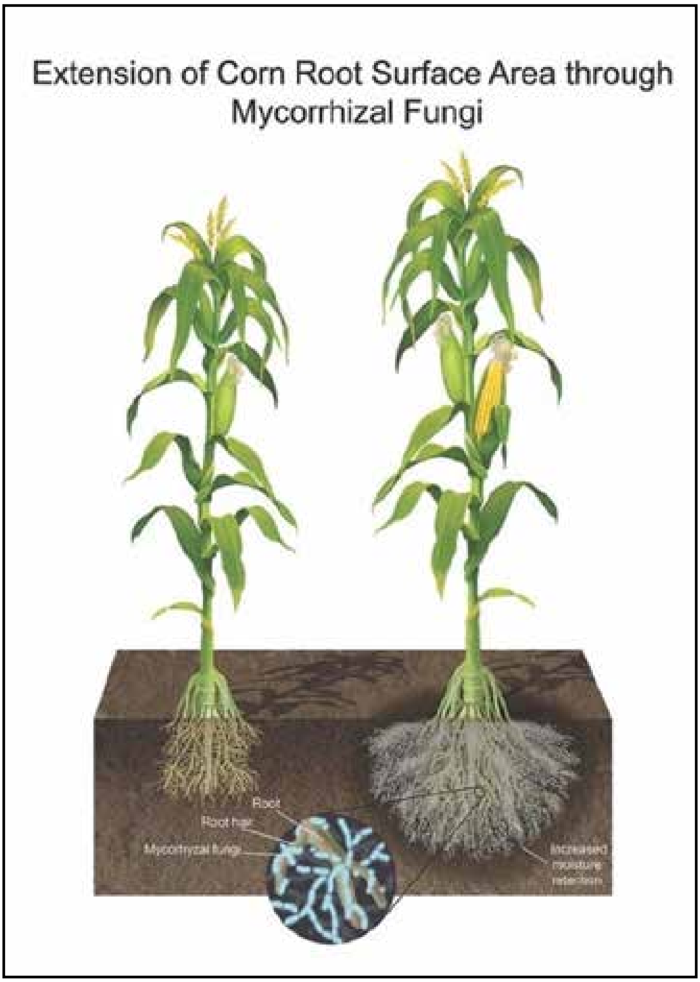
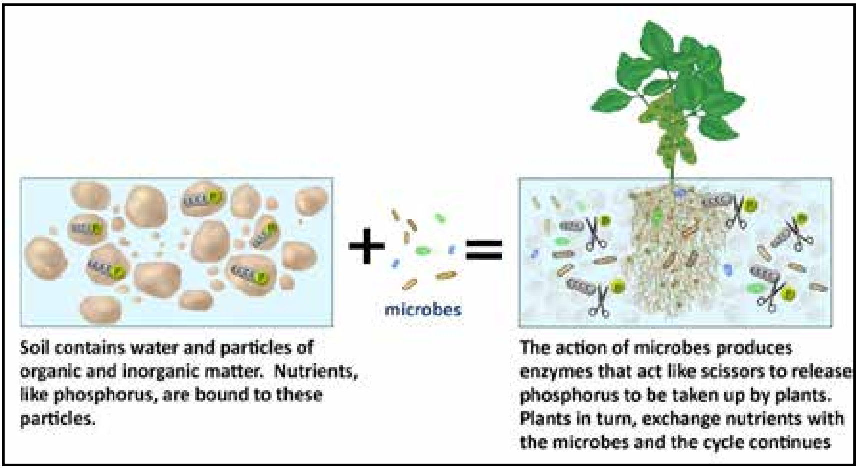


Illustration of mycorrhizal fungi allowing crop roots to access more nutrients and water in the soil. Illustration by Carlyn Iverson, courtesy of SARE.

solubilize a variety of nutrients that are otherwise bound tightly to the mineral fraction of the soil. For example, inorganic phosphorus can be in an insoluble form unavailable for uptake by plant roots, but the mycorrhizae are able to convert the phosphorus into a form that they provide to plant roots in exchange for sugars and other carbohydrates. As mentioned in Chapter 1, this exchange of carbon compounds for plant nutrients has been coined "carbonomics" by Keith Berns, a Nebraska farmer and president of Green Cover, a leading cover crop seed company.

Mycorrhizae have also been shown to provide water to plant roots in moisture-limited soils, which can be a big advantage for crops grown in healthy soils during times of drought. The exact reasons for this are not fully understood, and the amount of mycorrhizae-supplied water will not be enough to overcome a severe drought, but this phenomenon can help reduce stress on crops during a dry period.

Another factor that really helps during droughts is the role that mycorrhizae play in building better soil structure. One of the compounds exuded into the soil by mycorrhizae is glomalin, often called the glue of the soil. Glomalin helps bind together parts of the soil, allowing soil aggregates (building blocks) to form. When soils have



Microbes can impact phosphorus availability in multiple ways, including production of enzymes that help release phosphorus bound to soil particles. Illustration by Carlyn Iverson, courtesy of SARE.

more structure, they hold more moisture and usually have faster rainfall infiltration. Air exchange is improved from within soil pores to the surface and the soil becomes more resilient to compaction. All of these factors aid crop root growth, and with better root growth, the crop can reach more water and nutrients in the soil, a key way that healthy soils provide a more resilient growing environment for crops in tough weather.

Besides moisture stress, another stress on crop plants is disease. Mycorrhizae appear to help reduce certain crop diseases, in some cases forming a physical barrier to root diseases, and promoting crop health in other ways that lessen disease occurrence and impact.

While there is much more we can learn about the role of mycorrhizae, we already know enough to realize that soil management practices that include cover crops increase mycorrhizae in the soil. Eliminating or reducing soil disturbance is also important to protecting mycorrhizal fungi, as tillage destroys the hyphae and reduces fungi populations. Mycorrhizae need access to living roots year-round to thrive, so growing cover crops can help significantly in this regard (the only type of cover crop known not to promote mycorrhizae are the Brassica cover crops, which can be a reason to use Brassicas in mixes rather than as the sole cover crop).

Soil bacteria

Of the billions of microbes living in each teaspoon of healthy soil, most are bacteria, of which there are many, many types in the soil. To fully convey the complexity of soil bacteria is beyond the scope of this book, but a key point is that healthy soils have a diversity of bacteria and most play positive roles in the soil in respect to plant health and soil health. Bacteria have significant interactions with plant roots and fungi, contribute to converting and recycling nutrients, are eaten by many other soil organisms such as protozoa and nematodes, and fill other unique niches.

The soil bacteria most well-known to farmers are probably Rhizobium bacteria and other nitrogen-fixing bacteria that form symbiotic relationships with legume crops (and legume cover crops), generating nitrogen in a way that plants can't do on their own. However, they are far from the only bacteria that impact nitrogen levels. There are free-living nitrogen-fixing bacteria, other bacteria (nitrifiers) that convert ammonium into nitrate in the soil, and yet other bacteria that act as denitrifiers, converting soil nitrates into nitrogen gas that goes off into the atmosphere.

Bacteria don't work solely on nitrogen. Some of them are busy breaking down sources of carbon, alongside saprophytic fungi and other organisms. Many are active in the rhizosphere, the zone within a millimeter or so of the root surface, where nutrients are actively exchanged and carbon is cycling.

In the soil, like with all living systems, many bacteria act in concert with other organisms, living in the gut of earthworms, nematodes, or soil arthropods, and converting carbon and nutrients into different forms that help build soil health.

Other soil microbes

Nematodes and protozoa are other important classes of soil microbes that play a role in soil health. While farmers are well aware of problem nematodes like soybean cyst nematodes or root knot nematodes, most nematodes have no negative impact on plants and in fact play a beneficial role in the soil. Nematodes and protozoa both live in water-filled pores in the soil, and most subsist by eating bacteria. As they eat bacteria, they generally release some ammonium into the soil, some of which will be taken up by plant roots and the rest by bacteria and other soil microbes.

Ciliates are the largest of the soil protozoa classifications, and each can eat up to 10,000 bacteria in a day. Nematodes are even larger, feeding not only on bacteria but also other soil microbes, and even other nematodes. Nematodes can eat fungi, but conversely, there's a type of soil fungi that can trap and eat nematodes!

In comparison to the billions of bacteria that can live in a teaspoon of healthy soil, there may be up to a million protozoa but only a hundred or so nematodes living in that same teaspoon of soil.

Soil insects and other arthropods

If you asked most people to name a type of insect living in the soil, they'd probably come up with ants, which are certainly a common soil resident. Ants can have a big impact within soil ecosystems, eating other insects and even weed seeds. However, there are literally thousands of other soil-dwelling insects, some large like beetles, but many almost too tiny to see. If you were standing on a healthy soil, the area covered just by your shoes would typically contain hundreds to thousands of diverse insects and other arthropods.

While some of these insects can be pests to crops, most are simply part of the soil ecosystem, either helping break down plant residue or contributing to the overall food chain in the soil by eating smaller organisms and in turn serving as food for larger organisms, even birds and small mammals. Insects are part of the biological family known as arthropods, which also includes soil crustaceans like roly-polys (pill bugs), millipedes, centipedes, and mites, and help break down plant residue.

The big-picture view of soil biology

We are still gaining new insights into soil biology and will be for years to come. However, we already know much more about the important role of the soil biological community for crop health and soil health. Managing the soil in a way that supports a healthy microbial community makes sense if we want to optimize crop profitability and resiliency. Without doubt, cover crops are an effective management tool to feed the microbes in the soil and achieve better soil health.

CHAPTER 6

Simple steps for getting started with cover crops

For someone just getting started with cover crops, the sheer number of management choices can seem a bit overwhelming. The goal of this chapter is to simplify the options and narrow them down to the more tried-and-true approaches. Where appropriate, I'll mention viable alternatives, but I won't outline every possibility since the objective here is to provide a straightforward approach to some simple options for using cover crops.

This chapter will cover the basic steps for planting and terminating cover crops. Chapter 7 goes into selecting cover crop species. More details on equipment and specific strategies such as planting green, the approach of planting a cash crop into a still-living cover crop, will be addressed in later chapters. Specific topics covered in this chapter include:

- Seeding rates
- Seeding covers–timing
- Tips for overseeding covers into a standing cash crop
- Basic establishment methods for covers
- Termination of cover crops
- Other management adjustments to improve efficiency

Cover crop seeding rates

The next chapter outlines 44 different species of plants being sold as cover crops, and there are easily a dozen other species occasionally sold for cover crop use. While it would be nice to say there is an exact seeding rate to use for each species, that's simply not the case. When using pounds per acre as the seeding measure, the rate can depend in part on the size of seed for that variety and seed lot. Even more important for determining seeding rate is considering whether the cover crop is being used as the sole species planted or as part of a mix and what the goals are for the cover crop.

Taking cereal rye as an example, I've known farmers using anywhere from 15 pounds per acre up to 80 pounds per acre when planting it as the sole species. Most common is in the middle, around 50 pounds per acre. Particularly high rates may be used where the cover crop is going to be grazed and it's worth paying more for seed to get maximum forage. If broadcasting a cover crop, it's always wise to use a higher broadcast seeding rate than if drilling or otherwise direct planting the seed into the soil; the reason for this is that not as much seed broadcasted on the surface will sprout compared to seed planted into the soil. A general rule of thumb is to use about 30% more broadcast seed compared to drilling the seed, but it depends some on the type of cover crop and how well the seed works its way down into the cracks and crevices of the soil. Something like radishes that have small round seed are easy to broadcast establish don't need the broadcast rate boosted as much as oats, which are tougher to broadcast establish. Thus, I might boost radish broadcast rates by only 20% over drilling while boosting the broadcast rate for oats by 50% over drilling.

Farmers who are just looking to get some benefits from living roots may go with a lighter seeding rate. I know of a farmer in central Missouri who uses only 15 pounds per acre of cereal rye because he likes to plant his soybeans "green" into the living cereal rye and doesn't want too dense of a rye stand. I've stood in his fields in spring and he actually had a decent stand of rye, but certainly not as thick as higher seeding rates would provide. Those who are prioritizing weed control, biomass for organic matter, or erosion protection will want a higher seeding rate (and should plant the crop at a reasonable time to get it well established).

With mixes, adjust the seeding rates based on the number of species present and which species you wish to prioritize. For example, if planting cereal rye and crimson clover together, one approach is to simply cut the seeding rate of rye and clover each in half. However, the rye will outgrow the clover, especially in spring, so if you really want good clover growth, you might need to cut the rye to about 20%-25% of the normal rate and keep the clover rate at 70%-80% of normal. Green Cover has a free "SmartMix" seeding rate calculator to help determine seeding rates in multi-way cover crop mixes. To summarize a somewhat confusing topic, start by seeing what seeding rate is recommended by the seed company selling the cover crop variety. Then look at what Extension, NRCS, or other trusted advisors recommend for your area. The regional cover crop councils, such as the Midwest Cover Crop Council, have cover crop selector tools available for free use online that provide tips on seeding rates. Adjust the seeding rate to fit your goals for the cover crop and your seeding method. It's also worth doing a little experimenting, trying a few different seeding rates to see what works well for you.

When to seed covers

In the majority of cases, cover crops are fall-planted. Almost all fall cover crops benefit from being planted earlier in the fall rather than later. However, some cover crops definitely need to be planted while the weather is still warm to perform well, while others tolerate planting in mid-fall or late fall. A key question to consider when planning your seeding schedule is whether the cover crop is intended to overwinter. If so, planting date and other factors will affect winter survival. Of course, whether a given cover crop will over-winter depends on the region it is grown in, as well as planting date and other factors. For example, winter oats can overwinter fine in southern states but not the Midwest. Crimson clover overwinters in the southern Corn Belt but not the northern Corn Belt. Even variety differences can affect how far north a given cover crop will overwinter.

An example of how two weeks can make a significant difference in fall growth of crimson clover. One the left, clover planted on September 15; on the right, clover planted on September 30. Photos taken on December 2.

Cereal rye can be planted later than any other cover crop that is commonly used. As with the other covers, early fall is best and mid-fall is still okay, but late fall can work in a pinch. In northern areas, it's not unusual for cereal rye to be planted after the first fall frost has occurred. It may not grow much when planted late, but it has a remarkable ability to survive until spring even with a late-fall planting. Just keep in mind that erosion control will not be as good, nor will the rye root as deeply if fall planting is done late versus earlier. For fall grazing of rye (or any fall cover), early fall planting is particularly important, and higher seeding rates are helpful to maximize biomass.

Another point on timing the planting of covers is that covers that are broadcast-seeded often take longer, sometimes much longer, to start growing than ones planted with a drill or planter. If broadcast cover crop seed ends up sitting on top of dry ground, it can potentially remain unsprouted for weeks, waiting for a fall rain to come. Therefore, it's particularly important to accomplish fall broadcast seeding as early as possible, which is why some farmers broadcast cover crop seed into their cash crop prior to harvest.

Below is a table that outlines optimum planting windows in relative terms compared to other common cover crops. Sometimes covers are planted outside the time windows listed below, such as in mixes or possibly when inter-seeded in a cash crop.

Target planting window	**Species that don't overwinter in colder climates**	**Over-wintering species**
Early to mid-summer*	Sorghum-sudangrass Sunflower Sunn hemp Buckwheat Cowpeas Millets	
Late summer to early fall	Radishes Turnips Mustards	Rapeseed/canola Austrian winter peas Pennycress Camelina

Target planting window	Species that don't overwinter in colder climates	Over-wintering species
Mid-fall (ideally at least two weeks before average frost)	Oats Black oats	Crimson clover Balansa clover Hairy vetch Winter wheat Barley
Late-fall is tolerated		Cereal rye Triticale
Early spring **	Crimson clover*** Austrian winter peas*** Hairy vetch*** Oats Flax	Sweet yellow clover Red clover

**There is a long list of plant species that can potentially be used as summer cover crops. Only the most common of the warm-season covers are listed in the table. It should also be noted that some cool-season cover crops that are normally fall-planted are sometimes planted as part of a cocktail mix in mid-summer, just for convenience of planting the entire mix at one time.*

***Although cover crop planting in early spring is not common, sometimes it is done to fill in for a cover crop that did not become established in fall or failed to survive the winter. It may also be done with a biennial plant like sweet yellow clover that can be overseeded into winter wheat and allowed to grow the rest of the summer and fall right through to the next spring. Red clover is considered a weak perennial, meaning it can live for a few years once established, whether the planting is in fall or spring (assuming it's not terminated, which it normally would be for cover crop use).*

****Crimson clover, Austrian winter peas, and hairy vetch will generally overwinter if fall-planted in an appropriate climate; if these legumes are spring-planted, they will flower that spring, then either be terminated as covers or, if allowed to grow until maturity, die after setting seed by mid-summer.*

Tips on overseeding cover crops into a standing cash crop

One way to start cover crops growing earlier is by overseeding them into a cash crop like corn or soybeans before the cash crop is harvested. This overseeding can be done by airplane, helicopter, or high-clearance seeder.

The most commonly used approach to overseeding in commodity crops is to overseed into corn after the leaves start to turn color. At this point, light infiltrates better through the corn canopy and the cover crop seed has a better chance of establishing. Typically, there is a three-week window to plant the cover crop into corn between the first yellowing of leaves and harvest.

Soybeans are more challenging to overseed into successfully, mainly because the window for best timing is smaller–often only a week long. The soybean leaves must be turning color, but not yet dropping

The cover crop radishes on the left were drilled about the first of September and caught a light rain the day of seeding, coming up right away. The radishes on the right were drilled just a few days later but only part emerged as the soil was drying out, and most didn't emerge until another rain came a couple of weeks later. Photo was taken at the end of September.

on the ground. If too many soybean leaves are already on the ground when the cover crop is seeded, much of the seed may sit on top of the soybean leaves and not contact the soil. Additionally, if the cover crop is seeded too early, it can interfere with soybean harvest. A few inches of growth of grass covers like rye or oats is not usually an issue for soybean harvesting, but radishes or other broadleaves that get too big can cause too much green material to be collected by the combine head. A better approach may be to plant an earlier-maturity soybean where cover crops are to be planted, and then drill the covers immediately after soybean harvest.

In recent years, some farmers have had success interseeding cover crops earlier in the year, particularly into corn in the northern states. Various strategies for interseeding corn have been tried. Most often, interseeding has been done at the V3 to V5 stage by broadcasting cover crop seed among the corn plants. Some have used high-clearance seeders, such as the Cover Crop Interseeder (Interseeder Technologies), a high-clearance drill that can also spray herbicide and/or fertilizer solutions. A few farmers have even experimented with planting the cover crop at about the same time as corn is planted and trying wider corn rows to allow better cover crop growth.

Regardless of the method of interseeding, it's critical to give consideration to the herbicide program being used and how it might affect the cover crop(s) being interseeded. It may be necessary to use a different set of herbicide products to avoid killing the cover crop.

Establishment methods for covers

(More details on equipment can be found in chapter 9.) The most effective method for seeding most cover crops is to use a grain drill. A close second is to use a row crop planter, particularly one with split rows such as on a 15-inch spacing so the cover crop rows aren't too far apart. In fact, some farmers with split-row planters will seed alternating rows of two types of cover crops, such as radishes and rye or oats.

The advantage of either a drill or row crop planter over any type of broadcast seeding is better seed-to-soil contact. This is especially important in a dry fall or with larger-seeded cover crops such as Austrian winter peas. Small-seeded cover crops such as clovers, annual ryegrass, or Brassicas can generally be broadcast and establish effectively, especially if they receive rainfall soon after. Intermediate-size seeds like cereal rye and wheat are a little hit-or-miss when broadcast-seeded. If it rains shortly after broadcasting, they usually sprout, but sometimes there are complete failures with broadcast seeding, especially later in the fall. For this reason, it may be helpful to do broadcast seeding before combining or perform light incorporation with a vertical tillage tool or other implement. Keep in mind that some cover crops, like the clovers and Brassicas, need very shallow seeding, so a vertical tillage tool or other tillage implement may bury the seed too deep if the operator is not careful.

Regardless of the type of seeding method, the sooner the seeding is done in the fall, the better. I've heard many farmers say they have better luck broadcasting or drilling right after harvest, such as the same day, than waiting a week. This is because the cash crop residue may start to mat down and make it hard for the cover crop seed to establish, whereas right after combining, the residue is more fluffed up, and it is easier for the seed to make contact with the soil.

If you're short on labor during harvest, see if you can find a retiree or family member who wouldn't mind running a grain drill or broadcast seeder right after the combine. They might consider that an enjoyable job, and a rewarding one in terms of the conservation benefits of planting cover crops.

Termination of cover crops

One of the things that sometimes makes farmers hesitant to use cover crops is concern about dealing with terminating them in the spring. You do need a plan, but it's really not that complicated with most cover crops. If it is a big concern with you, start out with cover crops that winter-kill in your area–possibly oats and/or radishes. Something like cereal rye does have the deserved reputation of being relatively fast-growing once warmer spring weather comes around, but the good news is that cereal rye is very easy to kill with glyphosate. Some farmers planting soybeans following rye terminate the rye when it is still relatively small, such as 6-12 inches tall. Others let the cereal rye grow and terminate it the day they plant or shortly after (called planting green—see more on this approach in Chapter 8).

The main thing to be careful about when terminating cover crops is to either do it early or wait until planting. When problems usually occur is if termination is done roughly a week or two before planting, particularly if the cover crop is getting big and soil conditions are moist. Then you run the potential risk of a mat of dead cover crop residue preventing the soil from drying out. However, if the spring is a dry one, terminating a week or two ahead of planting may be an effective strategy. Just monitor your soil moisture conditions and adjust accordingly. The first time around, if you're nervous about it, just terminate early.

One other key consideration is to know the correct termination strategy for the cover crops you are using. As mentioned, cereal rye is straightforward to kill with glyphosate, even when it's several feet tall. Annual ryegrass, a completely different species, can be more challenging to spray-kill. I strongly recommend reading one of the several online publications about terminating annual ryegrass if you're using that crop. Other cover crop species may require a product other than glyphosate. For example, crimson clover and most of the clovers are easier to terminate with a combination of glyphosate and 2,4-D than with glyphosate alone.

Other management adjustments to improve efficiency

To maximize profit when using cover crops, here are some points to keep in mind:

- Use good-quality seed but use it efficiently. This means seeding the cover in such a way that a high percentage of the seed will grow and using a seeding rate appropriate to your goals. If the goal is only to obtain a modest amount of cover, a lower seeding rate may suffice. If the goal is good weed suppression or grazing use, a higher seeding rate will be needed.
- Plant the cover crop in a timely enough fashion to see full benefits from it. There's no benefit in throwing thousands of dollars

of cover crop seed on the ground in late November if it's not going to grow. Treat the cover crop like your other cash crops, meaning have a plan for its use, and be timely with operations. That way, you'll get a better return on your investment. Think of it like fertilizing: you apply your fertilizer early in the season, not late in the summer–otherwise you're wasting that input cost.

- ♦ Terminate in a way that helps rather than hinders your cash crop in the spring. Maybe you need to let the cover crop grow longer to suppress weeds or dry the soil for planting. Or maybe you need to terminate it early because there's dry weather or your planter is not set up well for planting into heavy cover crop residue.
- ♦ Be prepared to adjust your cash crop planter when planting into cover crop residue versus planting in conventional fields. It may take 20 to 30 minutes to get everything set optimally when switching from a conventional field to a cover crop field, but that time and effort will more than pay off in the form of a good stand of the cash crop.
- ♦ Consider where you might be able to cut some input costs in conjunction with cover crop use. You may want to maintain your existing herbicide and fertilizer regimen in the first year of cover crop use, but over time, you should find that you can cut back on certain inputs to gain cost efficiencies.
- ♦ As you gain experience with cover crops, think about what else you can change in your cropping system to improve overall efficiency. Maybe you can get by with less tillage, saving on fuel, labor, and equipment costs. Maybe you can plant some of your fields to earlier-maturing crop varieties, allowing you to spread out labor and start some cover crops earlier. Maybe some of those early cover crops can be grazed by you or a neighbor (who pays you a rental fee).
- ♦ Take time to monitor your soil, at a minimum with a shovel, but preferably with soil health testing. As when you get your own health checked by doctors, doing soil health checks will help you realize where your soil needs improvement and where you're making progress.

CHAPTER 7

Selecting cover crop species and mixes

There are dozens of species of plants currently marketed as cover crops in the U.S., and many more species that have potential for future use as covers. This chapter provides brief descriptions of 44 different species of cover crops, all of which I've grown and each of which have their own unique benefits. I personally believe there are some underutilized cover crops that will get more attention in the future as more testing is done and new varieties become more widely available.

Tips for starting simple with choosing a cover crop

The sheer number of cover crop species being sold can be a bit overwhelming if you are new to cover crops. In many situations, a good starting point is to fall-plant cereal rye in front of soybeans or cotton. If the commodity crop being grown is corn, cereal rye is not as good of a choice for first-time users, though it can work with appropriate management. In front of corn, I'd instead suggest a fall-planted mix of oats and radishes for easiest management. In the southern Corn Belt, an alternative that provides more soil protection and a little nitrogen fixation is to use oats with crimson clover; in the northern Corn Belt, I'd substitute hairy vetch or red clover instead or crimson clover, since they are more winter-hardy. In western regions where moisture is limited and small grains are grown, peas are often a good cover crop choice.

The regional cover crop councils have online cover crop selection resources, including fact sheets and cover crop selection tools, that you can use to help pinpoint a choice suitable for specific crops and locations. The Midwest Cover Crop Council has developed "cover crop recipes" that provide a short summary of how to get started with simple cover crop choices for each state in the Midwest. Talking with a nearby farmer experienced with using cover crops can also help zero in on a good starting choice, as can working with a knowledgeable cover crop seed company representative.

Tips for using cover crop mixes

Before getting into details on the individual cover crop species, I want to address the increasing use of cover crop mixes. While traditional commodity crop planting is done with a single cash crop in each field, cover crops offer the opportunity to mix things up. Of the farmers responding to the National Cover Crop Survey, about half started out using single species of cover crops and later added some mixes, while the other half used mixes on some fields right away. Where farmers were using mixes, about equal numbers were using a mix with two species, three species, four to five species, or six plus species. For beginning cover crop users, I think it's appropriate to consider using two or three species in a mix in some situations. One of the key advantages of a mix is that it makes establishment more likely overall, since even if one species fails to grow well, the other(s) may still establish.

Since a mix of cover crops provides a greater biodiversity of plants, it also tends to support a wider diversity of soil organisms and a healthier soil ecosystem. Mixes also tend to be better for wildlife and can attract and support beneficial insects and pollinators. Furthermore, a mix of species can help prevent invasion by weeds and lessen pest pressures.

When mixing species, try to pull from different plant families. A mix of rye and wheat–both grasses–is not as effective as a mix of a grass and a legume. Adding a member of the Brassica (mustard) plant family can work well with legumes and grasses. One of the more popular three-way mixes in the southern Corn Belt is cereal rye with crimson clover and radishes. Another factor to consider is whether the goal is to have at least one species or all species in a mix overwinter. For example, some options for fall-planted mixes are:

Family	**Fall growth only (winter-kill)**	**Overwintering species**
Grass family	Oats	Cereal rye
Brassica family	Radishes	Rapeseed
Legume family*	Berseem clover	Crimson clover

**Berseem clover can overwinter in regions with mild climates like the Gulf Coast or West Coast, and crimson clover can overwinter in the southern Corn Belt but not northern states. For northern states, more winter-hardy legume options include hairy vetch and red clover. Varieties can be important, too. "Frosty" berseem clover is somewhat more winter hardy than other berseem types and can overwinter as far north as Tennessee. "Fixation" is a new variety of balansa clover that seems to have moderate winter hardiness (both Frosty and Fixation are trademarked varieties of GO Seed).*

For erosion control and to keep living roots in the soil for as much of the year as possible, it is ideal to have at least one cover crop species in a mix that will overwinter to protect and improve the soil through spring planting.

More complex cover crop mixes tend to be used where the option exists to plant them mid-summer, such as after winter wheat harvest or harvest of an early vegetable crop. In these situations, some farmers have been planting mixes of 8-15 species, often referred to as cover crop "cocktails." Cover crop cocktails are planted in early or mid-summer, and usually consist primarily of warm-season covers. Often, some cool-season cover crop species are added in. The cool-season covers don't thrive in the middle of the summer but will tend to grow a little under their taller heat-loving summer companions. Then, when fall comes, the cool-season covers' growth takes off (if they've survived to that point).

Warm-season cover crop species such as cowpeas, sunn hemp, buckwheat, millets, and sorghum-sudangrass tolerate heat and grow fast in the summer months but are usually killed by light frosts. Cool-season plants like wheat, canola, or crimson clover don't like heat and grow best in cool weather, with the ability to tolerate sub-freezing temperatures several degrees colder than warm-season cover crops. Some cool-season plants overwinter (like cereal rye), and others die once it gets cold enough (like oats and radishes). The table on the following page contains examples of both warm-season and cool-season cover crops.

Examples of cover crops that are suited more for warm or cool weather

Family	**Warm-season covers**	**Cool-season covers**
Grass family	Sorghum-sudangrass Sudangrass Pearl millet Foxtail millet Japanese millet Other millets	Cereal rye Triticale Wheat Barley Oats Annual ryegrass
Brassica family	None	Radishes Turnips Rapeseed (or canola) Camelina Pennycress Mustards
Legume family	Cowpeas Sunn hemp Mung beans Adzuki beans Pigeon peas Lablab beans	Clovers Vetches Austrian winter peas Faba beans Chickpeas Lentils
Other broadleaf covers	Buckwheat Sunflowers	Flax

When using a mix, keep in mind that seeding rates need to be cut back accordingly. A Nebraska farmer-owned seed company called Green Cover has a very helpful online tool to plan cover crop mixes, including seeding rates. It's called the "SmartMix Calculator," and can be used for free on their company website, www.greencoverseed.com.

Some mixes can be purchased pre-formulated, or you may be able to get a seed company or ag retailer to make a custom blend for you. Some farmers mix the seed after they receive it. As long as you have a variety of seed shapes in your mix, the seed will probably avoid segregating when moved around; however, mixes of two to three

Mixture of crimson clover, hairy vetch and cereal rye in mid-spring.

species that are all rounded seeds are more likely to have a segregation problem where the smaller seeds go to the top or bottom of the container, depending on relative densities of the various seeds. In such a case, be prepared to check the seed right before planting and use a stick or other implement to stir the seed and remix it. Or, if using a drill, two different seed boxes can be used to keep the seed separated and meter it at the appropriate rate for a two-way mix.

Brief summaries of individual cover crop species

As was mentioned in the previous chapter, there are many cover crop species to choose from, although some are much more readily available than others. What is still lacking is much diversity in variety choices. For some of the less common cover crop species, there are literally no choices available in varieties, so you just have to buy the "common" seed of the species. Even for some of the most common cover crops, like crimson clover, there are only a few varieties that

Two varieties of balansa clover: Fixation on the left and Frontier on the right.

have been released. This has led to a situation where most of the cover crops being sold are sold as "Variety Not Stated" or VNS seed.

If named varieties are available for the cover crop species you are interested in, see if there's one that suits your needs. Often the named varieties will outperform VNS seed or, at the very least, allow you to better identify seed material with the traits you want. An example of how variety can make a big difference is illustrated in the photo of two varieties of balansa clover above–one with early flowering that achieved little spring growth and one with delayed flowering, vigorous growth, and overall superior performance for biomass and nitrogen fixation. (Visit www.sare.org/cover-crops for more information on species selection, including links to selection tools offered by the four regional cover crop councils.)

Legume cover crops

Legumes are popular cover crops because of their ability to fix nitrogen and general contributions to soil health. There are some legumes like crimson clover and balansa clover that, as winter annuals, are best suited to cool weather conditions of fall and spring. There are other legumes like cowpeas and sunn hemp that grow best in the heat of summer. Below, I've broken down both legumes and other cover

Crimson clover on the left, balansa showing over 3 feet of growth in Missouri by mid-May on the right.

crop types into the cool-season options and warm-season options. When using legumes as cover crops, remember to add an inoculant designed for that particular legume to the seed in order to ensure that it will fix nitrogen. While legumes are well worth considering for use as cover crops, be aware that seed costs can be somewhat higher than for grasses or Brassicas, so in a mix, keep the seeding rate of the legumes appropriate to the goals you have for that cover crop system. For example, for grazing, a higher rate of legumes may be worth the extra seed cost, but if the goal is simply to increase biodiversity in a mix, a lower rate may be more appropriate.

Cool-season legumes

Crimson clover. This is the most common legume cover crop used in the U.S., but its mediocre winter-hardiness means it is limited to areas with milder winters if it's intended for fall planting and overwintering. In the Midwest, crimson clover (*Trifolium incarnatum*) can generally be used south of Interstate 70. In the west, it can be used in milder areas of the Pacific Northwest. In addition to having mediocre winter hardiness, its other primary limitation is that it doesn't like wet soils during the winter; there are better choices for poorly drained fields. On the plus side, crimson clover is fast-establishing, generally easy to grow, and beautiful in bloom. Dixie is the most widely sold crimson clover variety but is considered to be a mix of material that may not be entirely true to type. Kentucky Pride is a recent variety developed by the University of Kentucky that is believed to be more winter-hardy than Dixie, with later flowering and reports of better nitrogen fixation. I expect that additional varieties will come on the market in the next decade.

Like most of the legumes, it can take more than glyphosate to kill crimson clover; usually, adding 2,4-D or other broadleaf product is needed for effective herbicide termination. Otherwise, it can be roller crimped or mowed after flowering to terminate. Of all the cool-season legumes, for my area (Missouri), crimson clover is the one I like best if I want to plant just a single legume in the fall by itself. It provides a decent ground cover in the fall and gets off to a relatively fast start in the spring.

Balansa clover. The "Fixation" variety of balansa clover (*Trifolium michelianum*) is a relatively new entrant into the cover crop market from GO Seed, and early testing indicates that it may be somewhat more winter-hardy than crimson clover. I've found it to be a little less vigorous in the fall and early spring than crimson clover, but once it gets going in mid-spring, it puts on very impressive growth. I've had it grow up to 40 inches tall. Considered bloat-resistant, it can be a good option for spring grazing and, like crimson clover, it is a good option in cover crop mixes.

Red clover. In more northern states, red clover (*Trifolium pratense*) is usually the best option for those wanting a clover that can overwinter. It's a tough winter perennial with a long history of use in pasture mixes. Another advantage is its ready availability through most seed dealers due to its popularity for forage use. However, it's not as fast-growing as crimson clover, reflecting its perennial nature. The slower establishment and growth of red clover explains why crimson clover is the preferred choice over red clover as a clover cover crop in southern states.

Yellow sweet clover. Though much less common than it used to be for cover crop use, yellow sweet clover (*Melilotus officinalis*) is worth mentioning as an option for those who want a biennial type of growth habit. On the central Illinois farm where I grew up, my dad used yellow sweet clover for many years, overseeding it into winter wheat as a frost seeding in early March, then allowing it to grow after wheat harvest until the following spring, when he would plow it in as a green manure crop. Used in this fashion, yellow sweet clover can fix a large amount of nitrogen. This plant is now frowned upon by conservation officials in some states because of its ability to survive and reproduce in roadside ditches and other perennial settings. I've seen it growing wild along miles of roadways in Nebraska, but only occasionally in Missouri and other parts of the Midwest; it's certainly not as aggressive as some non-native plants. Still, review whether it's an invasive concern for your area before planting. There is also a white-flowering sweet clover which is less common in the cover crop market, and despite the similar common name is actually a different species of plant (*Melilotus alba*).

Other clovers. There are a number of other clovers sold in the cover crop trade but most are either used in targeted situations or as parts of diverse multi-way cover crop blends with 10 or more species. Of the other clovers, the newest one on the market is Persian clover (*Trifolium resupinatum*), which has some promise but only mild winter hardiness. White clover (*Trifolium repens*), also called ladino clover, is commonly seen in lawns and is sometimes used in cover crop mixes or as a sole cover crop for planting in row areas between vegetables or fruit crops. Berseem clover (*Trifolium alexandrinum*) is perhaps the next most common clover used in cover crop mixes, but like Persian is best suited to southern areas due to lack of winter hardiness.

Hairy vetch. For more northern areas, hairy vetch (*Vicia villosa*) is usually the best choice of cool-season legume because of its superior winter hardiness compared to crimson clover and Austrian winter pea. This contributes to it being the second-most popular legume cover crop in the U.S. It can be a prolific nitrogen fixer if allowed to grow long enough and can be effective at smothering weeds, either planted alone or as part of a mix. One weakness is its lack of fall biomass, so I usually recommend it be planted with a grass cover crop–either oats or cereal rye. For people growing wheat for grain, it's best to avoid using hairy vetch in the rotation, because the hairy vetch may become a weed in the wheat crop and is difficult to separate from harvested wheat seed during the combining process.

Other vetches. Common vetch (*Vicia sativa*) is a different species of vetch sometimes sold for cover crop mixes, though hairy vetch is usually preferred due to its more vigorous growth and better winter hardiness. Crown vetch (*Securigera varia*) has been used as part of perennial mixes for roadside plantings, but it is considered invasive in some areas. It is a different genus and species of plant from hairy vetch. Another very different plant loosely grouped with vetches is chickling vetch (*Lathyrus sativus*), also known as Indian pea. It is sometimes sold as a cover crop and has respectable nitrogen fixation potential.

Austrian winter pea. The two biggest benefits of Austrian winter peas (*Pisum sativum var. arvense*) in my mind are their high potential for nitrogen fixation and easy termination. They have intermediate winter hardiness–somewhat better than crimson clover, but not as good as hairy vetch or red clover. However, their survival through winter depends on planting them properly and at that right time of the fall for a given area. Paul Jasa from University of Nebraska has found that, for his area, planting them at least two inches deep or more can improve their winter survival. That may not be feasible on

Hairy vetch on left with purple flowers in mid-May in Missouri. Lentils on right in late fall from two planting dates.

all soils, but it is worth testing for your area. In Missouri, if planted by early September, they can put on impressive fall growth; if planted in October, on the other hand, they don't grow much at all until spring rolls around. Like hairy vetch, I prefer to plant Austrian winter peas in a mix instead of as a sole species.

Faba bean. The next few cool-season legumes mentioned—faba (or fava) bean (*Vicia faba*), chickpea, and lentil—are all Mediterranean crops that are normally fall-planted in that region and grown for seed harvest. In the northern two-thirds of the U.S., however, these three species will winter-kill, so they are best used as part of a diverse mix of cover crops planted in mid-to-late summer, or even as part of a spring mix. Faba beans can grow well in cool weather, but they have a large seed that is not well-suited to broadcast seeding and is somewhat more expensive and difficult to find than other legumes mentioned here.

Chickpea. Chickpeas (*Cicer arietinum*) and lentils are often mentioned together and are grown for seed harvest as spring crops in the Pacific Northwest. Like faba beans, they are best used as part of diverse mixes of cover crops planted in mid-to-late summer or as part of a spring mix. Chickpeas could be used as a winter cover crop in southern parts of the U.S., such as plant hardiness Zone 9 or warmer areas.

Lentil. Lentils (*Lens culinaris*) are another cool-season legume best used as part of diverse mixes of cover crops planted in mid-to-late summer or as part of a spring mix. Lentils are somewhat more winter-hardy than chickpeas or faba beans, reportedly able to tolerate down to the low single digits, so they could be used as a winter cover crop (again in mixes) in the southern part of the U.S., possibly Zone 7 or warmer areas.

Warm-season legumes

Cowpea. The most popular warm-season legume is cowpeas (*Vigna unguiculata*). The first thing to know about cowpeas as a cover crop is that varieties can be grouped into two types. The type best for cover cropping is the indeterminate (viney) type of cowpea; iron clay cowpeas are a viney type that is often sold for cover crop use or wildlife plantings. There are also determinate (bush) type cowpeas that can be used for cover cropping but are more normally used for seed harvest. Cowpeas are good nitrogen fixers and are tolerant of dry conditions. They might occasionally be used as the sole summer cover crop, such as after an early-season vegetable, but they are more often used in row crop systems as part of a diverse summer mix of cover crops.

Mung bean. Part of the same genus of plants as cowpeas, mung beans (*Vigna mungo*) can be used as a substitute for cowpeas or in a mix with cowpeas and other summer cover crops. They are bush type and therefore have a more upright growth habit than viney cowpeas, but they are shorter and less vigorous than soybeans. They are tolerant of dry conditions and light-textured soils.

Adzuki bean. Adzukis (*Vigna angularis*) are also part of the same genus of plants as cowpeas and are fairly similar to mung beans in their niche for cover crop use. Somewhat harder to find than mung beans or cowpeas, they are usually more expensive as well, but can add some diversity to a cover crop mix if available. Their vigor and size is similar to mung beans and they have a bushy growth habit.

Sunn hemp. Considered a tropical legume, sunn hemp (*Crotalaria juncea*) will flower but not actually produce seed in most parts of the U.S., as it needs a longer growing season. In warmer areas, if planted

Photo on left shows sunn hemp in back with yellow flowers, faba beans on lower left, and annual rye grass to lower right in image. Photo on the right is lablab beans in full flower.

by mid-summer, it can put on an impressive amount of growth, often reaching 6-8 feet tall or more. Research on its ability to fix nitrogen shows it producing an impressive amount of nitrogen, similar to cowpeas. It also has good forage potential as part of a mix. The most common summer legume cover crop in the U.S. is cowpeas and the second is sunn hemp, and the two can work well together in a diverse summer mix with warm-season grasses and other species. By the way, sunn hemp is not related to industrial hemp (*Cannabis sativa*).

Pigeon pea. Another tropical legume, pigeon pea (*Cajanus cajan)* has seldom been grown as a seed crop in the U.S., but it has garnered some interest in southern areas as a cover crop in mixes. I was impressed by the vigor of a couple of pigeon pea cultivars I field tested twenty years ago, but they were different from what's on the market today, so I'm not sure how they compare. This is another cover crop that can be tough to find but is worth having if offered in a mix.

Lablab bean. I've grown lablab beans (*Lablab purpureus*), also known as hyacinth bean, in my garden for years as an ornamental plant. They produce colorful purple flowers as they climb on my garden fence and then showy purple seed pods in late fall. They are also a tropical legume and take a while to establish, but once they start growing they can put on an impressive amount of growth. They are a vining plant that I've seen grow 6-7 feet long if they have something to climb on. If grown unsupported, they stay shorter, with the vines growing in all directions. I wouldn't use lablab beans in cooler areas, but they have potential as part of mixes used in the southern half of the U.S. Seeds are expensive, however, and hard to find in bulk.

Grass cover crops

The most compelling reasons to use one or more grasses in cover crop systems is their fast growth, good rooting, and potential for significant biomass. If a long period of residue cover is desired, grasses such as cereal rye can be used alone and the residue should persist for several weeks. If the goal is to have the residue break down faster, mix the grass cover crops with a legume and/or Brassica to obtain a carbon to nitrogen (C:N) ratio that will allow the soil microbes to decompose the cover crop residue more quickly.

Cool-season grasses

Cereal rye. Sometimes called the "queen of cover crops," there's no question that cereal rye (*Secale cereale*) is the most popular cover crop across a broad swath of the U.S. In the north, it is valued for its extreme winter hardiness and ability to be planted in late fall; in the south, it is valued for its weed-suppression benefits; and it is valued everywhere for its high biomass and low cost. The one area where it is seldom used is in arid parts of the west, where there's a need for cover crops that use minimal water, like peas. Another situation where rye is discouraged is in rotations that include wheat for grain harvest, because of potential contamination of wheat seed with rye seed.

There are several varieties of cereal rye on the market, and I expect more in the coming years. Much of what is sold is VNS, but buying a named variety is generally preferable to ensure you get a variety suited to your region; there are varieties of rye more suited to the south, and some better for the north. Rye is also the cover crop most commonly grown by farmers for their own use and sold to neighbors. Buying from a neighbor is fine, but make sure the seed has been tested for germination percentage (which should be 85% or above), and that it has been thoroughly cleaned and is free of any weed seed.

Cereal rye can be planted later than any other cover crop in the fall. If planted very late, such as when hard freezes are setting in, the rye may not emerge until spring, which means it will not help prevent winter erosion but can help prevent spring erosion. A caution for first time growers of cereal rye is that it can put on growth very quickly in the spring, so be prepared with a timely termination strategy that fits your crop management system.

Triticale. Some farmers prefer triticale (*Triticosecale*) over cereal rye for ease of spring management. Triticale is a hybrid of rye and wheat, and has some of the benefits of each; it is more winter-hardy than wheat but has more moderate spring growth than rye. Farmers grazing cover crops may also prefer triticale over rye. Triticale can have slightly better feed quality than rye but usually produces somewhat less total forage than rye.

Wheat. Winter wheat (*Triticum aestivum*) is used on more cover crop acres than triticale, likely because it is easier to buy and usually cheaper. Winter wheat does need to be planted a little earlier than triticale and up to 10-14 days earlier than the latest rye planting date; it is important to note, however, that it should be planted after the Hessian fly free date for any given area. It is also less winter-hardy than either rye or triticale, but will overwinter in most parts of the U.S. if planted on time in the fall. Wheat is sometimes preferred over rye when used for cover crop grazing, as wheat can have higher feed value; the tradeoff can be less total biomass than rye.

Barley. The best use for barley (*Hordeum vulgare*) as a cover crop is grazing. It is also sometimes used in more southern areas as an over-wintering cereal, and produces less spring biomass to contend with compared to the winter cereals outlined above. This reduced amount of biomass may also be considered a downside in some situations. Moreover, barley is not quite as winter-hardy as other winter cereals, which limits its use to areas with more moderate winters. It is a good species for grazing, similar to other winter cereals, and is preferred by some grazers for fall grazing; wheat and/or triticale are often preferred for spring grazing.

Oats. After cereal rye, oats (*Avena sativa*) are the most-planted grass cover crop. The big difference from all the grasses listed above is that oats winter-kill in the northern two-thirds of the U.S., which for many farmers is a main reason to use them. The idea is that use of fall-planted oats makes spring cash crop planting easier because there's less residue to deal with, and potentially nothing to terminate. Personally, I think that oats have a place for new users of cover crops, or sometimes as a grass to use with a brassica and/or a legume in front of corn. I've noticed in my own experience that seeding oats at a modest rate, such as 15 pounds per acre, can help a legume like crimson clover or hairy vetch survive the winter. I think this is because the oats help trap snow that protects the legume and reduce the desiccating action of winter winds on the more tender legumes.

The type of oats most often used for fall cover crop planting are spring oats, which are also the most widely available and cheapest type of oats. The next most commonly used type is winter oats, sometimes called "Bob oats." There are also two types of black oats; black-seeded oats are similar to other winter oats except with darker seed. There's a black-seeded winter oat, also known as Cosaque oats. There's also a true black oat that is a different species (*Avena strigosa*), but relatively few seed companies offer it for sale.

Annual ryegrass. Annual ryegrass (*Lolium multiflorum*) is a relatively popular cover crop, but also a controversial one. This is because of its potential to become a herbicide-resistant weed–something that troubles the weed science community. Annual ryegrass has been used as a common annual forage for a number of years and, if carefully managed, it may be possible to avoid it becoming a weed issue. The advantages of annual ryegrass are its very easy broadcast establishment, fast growth, and relatively deep rooting. While not as winter-hardy as cereal rye (which is a totally unrelated plant) or even winter wheat, it can overwinter in the southern half of the Corn Belt. If annual ryegrass is used, it's important to pay close attention to recommended herbicide control strategies and to plant a single named species rather than VNS seed, which can be a mixture of varieties that end up being more difficult to control.


Late fall photos of annual ryegrass on the left and oats on right, with spring oats in back and black-seeded winter oats in front.

Warm-season grasses

Sorghum-sudangrass. A hybrid member of the sorghum (*Sorghum bicolor*) family, sorghum-sudangrass is a popular component of summer cover crop mixes due to its fast growth in warm weather. Sorghum-sudangrass can produce more biomass than straight sudangrass, but some may favor sudangrass for its finer texture and reduced risk of prussic acid poisoning for grazing animals (to completely avoid risk of prussic acid, use pearl millet as an alternative summer cover crop).

Forage sorghum. Most people are familiar with the grain type of sorghum (*Sorghum bicolor*), which has semi-dwarf plants bred for high seed yield. However, for cover crop use, the forage sorghums are a better choice than grain-types. Forage sorghums typically grow over seven feet tall if planted in June. Forage sorghum varieties are widely available in the seed trade and are vigorous plants that can produce a significant amount of biomass. There are even taller "biomass sorghums," but those are less widely available. Sorghum, domesticated as a food crop in Africa, does well in hot, dry conditions. It is less suited to areas with cool summers.

Pearl millet. Like sorghum, pearl millet (*Pennisetum glaucum*) was domesticated in Africa as a food grain but made its way to the U.S. primarily for forage use. Most of the pearl millet varieties sold in the U.S. are forage-types that typically grow 6-7 feet tall if planted in June; there are a few grain-type pearl millets that are shorter in stature, more typically about four feet tall. For cover crop use, the forage-types are preferred and are more readily available. Pearl millet has a fibrous root system like sorghum and is able to grow in hot, dry conditions. It is tolerant of sandy soils but will grow in heavier clay soils as well. Pearl millet is an excellent option for warm-season cover crop mixes and has the added benefit of providing seed enjoyed by several types of songbirds, including goldfinches.

Foxtail millet. Originating in Asia–most likely northern China–foxtail millet (*Setaria italica*) is a very different plant from pearl millet, both in appearance and genetics. A cousin of the weedy foxtails, but not weedy itself due to its domestication as a food crop, foxtail millet will generally grow 3-4 feet tall if planted in June, and shorter if planted later in the summer. Foxtail millet has relatively fast growth and is tolerant of dry conditions. It's a good species for adding diversity to a summer cover crop mix, and its seed is eaten by a variety of songbirds and game birds.

Japanese millet. For sites prone to flooding or excessively moist soils, Japanese millet (*Echinochloa esculenta*) is the best choice among the millets and annual summer cover crops. It can also tolerate drier upland sites, but its unique niche is in wetter situations, perhaps reflecting its origin in southeast Asia. Japanese millet is often promoted for supporting ducks or other waterfowl, but it's eaten by some other birds as well, and is a reasonable choice for summer cover crop mixes. Japanese millet will typically grow about four feet tall if planted in June, and shorter if planted later.

Browntop millet. Similar in stature and maturity to Japanese millet, browntop millet (*Urochloa ramose*) is also from southeast Asia. It can tolerate damp soils but not flooded soils. It can also tolerate drier upland situations. It may not be as easy to find as some of the other millets, but it is sold some for wildlife planting and is yet another way to add diversity to the grasses used in a summer cover crop mix.


Pearl millet on the left and foxtail millet on the right.

Teff. Sometimes loosely grouped with the millets, teff is an African grain crop most common to the highlands of Ethiopia. Compared to the other grasses mentioned here it is much shorter, generally only growing about two feet tall. The main reason I mention it here is because of its potential to be used as a quick cover that is well-suited for grazing in hot, dry conditions. It can also be used as an effective hay crop, including for horses.

For more information on millets as cover crops or other uses, do a search for "University of Missouri millets" and you'll find an Extension guide I wrote on that topic. I have written similar Extension guides on buckwheat, sunflowers, and canola that can be found in the same way.

Brassica cover crops

All of the currently available Brassica cover crops on the market are cool-season plants. Brassicas can provide quick cover, help reduce populations of certain nematodes, are effective at sequestering nutrients, and are a good option where vole pressure is high since voles don't seem to like Brassicas as well as other cover crops (slugs, however, do eat Brassicas). The small, round seed is also easy to broadcast-establish, allowing for a variety of seeding methods.

Radishes. When I hear someone say there's nothing new about cover crops, one of the things I point out is there are species being used now, like radishes (*Raphanus sativus*), that weren't part of the cover crop picture in past decades (other cover crop practices have of course changed, too, like planting green and seeding techniques). Steve Groff, a Pennsylvania farmer, and Ray Weil, a University of Maryland soils professor, were two of the first to see the potential of radishes in the U.S. Steve led the effort to popularize a variety trademarked Tillage Radish, which gained a huge following and helped make the radish species the most popular of the Brassica cover crops.

Radishes have been used widely because of their quick fall growth that prevents winter weeds from establishing, their ability to sequester soil nutrients, and the fact that they winter-kill in most of the


Forage (daikon) radish on the left, turnips on the right, both photos from late fall.

Corn Belt and so are out of the way for planting spring crops like corn. The fact that they winter-kill is a bit of a downside, however, because it means they lack erosion-control benefits; for this reason, I prefer to see them used with a winter cereal that can help hold the soil in place until spring. Radishes also have the benefit of being able to broadcast-establish relatively easily, which is good because they need to be planted in early fall to provide maximum benefit, meaning they are often flown on or otherwise broadcast into summer crops such as corn and soybeans prior to harvest. The two main types of radishes sold for cover crop use are forage (daikon) radishes and oil-seed radishes. The forage type has a larger tuber and is more popular in the marketplace. The oilseed type has a smaller, shorter tuber but may have a little more potential for overwintering in mild climates, depending on variety.

Turnips. For cover crop use, turnips (*Brassica rapa*) have a lot of similarities to radishes, as they are planted at the same time in early fall and have similar fall growth. The main difference between them is the shape and size of their tubers, with radishes having a tuber that is long and narrow and turnips having a shorter and squatter tuber. In grazing situations, turnips are generally preferred over radishes, since cattle in particular will eat turnip tubers even when the ground is frozen. However, for straight row crop situations, radishes are generally preferred since turnips can occasionally create a bit of a challenge for planting the cash crop, depending on how big they get in the fall and how long they have to decay in the spring.

Canola in early November on the left and on the right a canola field in a late April in Missouri.

Rapeseed (or canola). As the second biggest oilseed crop in the world after soybeans, canola/rapeseed (*Brassica napus*) is known more as a commodity crop than as a cover crop. Canola is by far the most commonly grown type of rapeseed. The only difference between canola and other rapeseeds is that canola varieties are lower in erucic acid and glucosinolates than other rapeseed varieties. That makes canola better suited for food uses. For cover crop purposes, the oil characteristics don't really matter, so winter hardiness and whether to use spring versus winter types of canola/rapeseed become the bigger considerations. I like winter canola varieties for cover crop use as an alternative to radishes; unlike radishes, canola can overwinter and better protect the soil, while providing living roots for more months. However, there can be situations where radishes are preferred for mixes or because a farmer does not want something that overwinters and has to be terminated. Winter canola/rapeseed varieties also have their limits in how far north they can be grown. A general guideline is that they can overwinter in the southern half of the Corn Belt, or roughly south of Interstate 70 (maybe Interstate 80 in a milder winter and if planted early enough). They also overwinter well in parts of the Pacific Northwest with milder winters. Canola can be grazed as a sole cover crop or, better yet, as part of a mix, although it may take cattle a few days to get used to the taste of it.

Pennycress. Pennycress (*Thlaspi arvense*) is a plant native to Eurasia that sometimes shows up as a minor weed in U.S. crop fields. A company in St. Louis called CoverCress has been working to develop improved varieties of pennycress which will be sold under the CoverCress trademark. The improved type of CoverCress is being positioned as a plant providing some cover crop benefits that can also be harvested in late spring for oilseed use, followed by soybean planting. The market for CoverCress as an oilseed needs further development, but it certainly has some promise, and I'm interested to see how it progresses in the marketplace. It has the potential to provide an economic boost in a crop rotation while serving as a winter cover crop protecting the soil.

Camelina. Camelina (*Camelina sativa*) is a European plant that has seen some use as an oilseed and interest as a winter-hardy cover crop. There are some potentially promising uses for camelina seed oil, which have led to it being grown on a small scale in northern and northwestern states. Both winter and spring types of camelina are available, with the winter type being the one used for cover crop purposes. Some experiments in Minnesota and other states have looked at interplanting soybeans into camelina and then harvesting the camelina in June, while the soybeans are still small. Camelina doesn't mature for seed harvest quite as fast as the new varieties of CoverCress, but it appears to be more winter-hardy, which has driven the interest in using it as a cover crop in northern areas.

Mustards. The true mustards include brown mustard (*Brassica juncea*) and white mustard (*Brassica alba* or *Brassica hirta* or *Sinapsis alba*). Brown and white mustard don't get used too often for cover cropping, but they are occasionally used in diverse mixes of cover crops. In my limited experience with them in Missouri, they aren't as vigorous in the fall as radishes, turnips, or canola are. However, some of the mustard varieties may be more bioactive in ways that could provide benefits for fighting certain soil-borne diseases or pests; more research on this is needed.

Other brassicas. There are many plants that are members of the Brassica plant family, including common vegetables such as cabbage, kale, arugula, cauliflower, and broccoli, and a wide range of wild Brassicas such as yellow rocket (*Barbarea vulgaris*) that show up in many crop fields in early spring. I expect we'll see more novel

Brassicas tried as cover crops in the coming years. In Missouri conditions, one that has stood out to me for strong fall growth is Africa cabbage (*Brassica carinata*), also called Ethiopian cabbage or Ethiopian mustard. If planted in early fall, it can put on an impressive amount of biomass. However, it will normally winter-kill in Zone 6 or colder climates.

Other common cover crops

Buckwheat. Among the cover crops that don't fall into the categories of grasses, legumes, or Brassicas, buckwheat (*Fagopyrum esculentum*) is the most popular option. Long used by vegetable growers as a summer cover after early-season vegetable harvest, buckwheat is now used frequently in multi-way cover crop blends in grain crop rotations, mainly after small grain harvest. The three main attributes of buckwheat for cover crop use are fast growth, soil improvement, and a long flowering period. I've grown over 70 species of economic crops, and buckwheat is the fastest from emergence to flowering, putting on quick growth that can help smother weeds to an extent. However, vigorous summer weeds can outcompete buckwheat, especially if the buckwheat stand isn't thick. From a soil improvement standpoint, I've heard some farmers say they feel buckwheat mellows the soil. That's a subjective observation, but it is somewhat more documented that buckwheat seems to help make phosphorus more readily available in the soil to following crops in the rotation. Buckwheat's long flowering period is a plus for pollinators and other beneficial insects, and is another reason it is popular in mixes.

Flowering field of buckwheat on left and fall-planted flax from early November on right.

Sunflowers. Sunflowers (*Helianthus annuus*) have some similar benefits to buckwheat but are a much different plant in terms of height and growth habit, making them complementary members of a diverse mix. The most commonly sold sunflower in cover crop mixes is a Russian type also sold for wildlife use called Peredovik sunflower. However, I feel the commercial oilseed sunflower varieties are just as good of choices for cover crop mixes, and may even be superior because of their leafier growth and overall vigor. Sunflower, like buckwheat, is a plus for pollinators, but it doesn't bloom for nearly as long. Sunflowers can be helpful in suppressing weeds and have a deep taproot that can help loosen up tight subsoils. Even a small amount of sunflowers in a summer cover crop mix can be a positive thing from a diversity standpoint, and certainly adds some beauty to the field when flowering.

Flax. While buckwheat and sunflower grow best in summer, flax (*Linum usitatissimum)* is more of a cool-season plant. If planted for seed harvest, it's normally planted in early spring around the same time as oats, producing seed in late July or early August. As a cover crop, its main use is to diversify summer or fall cover crop mixes. If planted in summer, it can provide a period of flowering in the fall–a positive for beneficial insects. The blue flowers of flax are attractive, as is the plant overall, but the small leaves don't provide much in the way of competition for weeds. I've grown flax quite a bit for seed production plots and in cover crop mixes; it wouldn't be a high priority for me to add to a mix, but if I were doing a blend of 10 or more species, I would certainly consider flax from a diversity standpoint.

CHAPTER 8

Maximizing cover crop benefits by planting green

Planting green is a term referring to planting a cash crop directly into a still-living, green cover crop. In planting green approaches, the cover crop is normally terminated either in the same tractor pass as planting or soon after planting the cash crop. In the most recent SARE/CTIC National Cover Crop Survey, over half of the farmers reported using this approach on at least some of their fields.

I first heard about the idea of planting into a still-living cover crop in a presentation by Jeff Moyer at a 2008 SARE conference in Kansas City. At that time, Jeff was the farm director at the Rodale Research Institute in Pennsylvania. He and Steve Groff, a Pennsylvania farmer, were probably the first two people to extensively test roller crimpers for cover crop termination. At the conference, Jeff showed videos of planting corn into a still-living cover crop, with a roller crimper mounted to the front of a tractor and planter towed behind. I don't recall hearing the term planting green until later, and I'm not sure who

University of Missouri trial with different planter settings and approaches while planting green with soybeans into still-living cereal rye.

coined the term, but I got firsthand experience with planting green a few years later in 2013 when we tested the approach at the University of Missouri Bradford Farm.

Tim Reinbott, the then-superintendent of Bradford Farm, organized a group of us to come out and experiment with several planter setups and roller crimper methods while planting soybeans into cereal rye that was already 5 to 6 feet tall. Planting into such big cereal rye represents one extreme of planting green. At the other end of the spectrum, one can plant into still-small cover crops that are only a few inches tall. I often tell audiences that as an agronomist I would never have believed you could successfully plant soybeans into 5- or 6-foot-tall cereal rye until I experienced it myself, but now I've heard success stories from many farmers who have done it.

In the 2013 trial at Bradford Farm, it quickly became apparent that planter setup really matters for successfully planting green. It also became obvious that leaving the cover crop plants upright to plant into can be very beneficial. This was a change in thinking from the earlier Rodale approach of rolling the cover crop in front of the planter; I think that model works in some situations, but not always as well as leaving the cover crop upright.

The advantage of leaving the cover crop standing at the time of planting is that there is much less of a problem with "hair-pinning" the cover crop residue into the cash crop seed furrow. If the cover crop is already rolled–something we were experimenting with in 2013–there's a greater chance of pushing some of the cover crop stems and leaves down into the furrow. If this hair-pinning occurs, the compressed stems and leaves can act to wick moisture out of the furrow, drying out some of the seed. A rainfall after planting can resolve that problem, but we can't always count on receiving timely rain after planting, of course.

The original Rodale approach was to roll the cover crop in the same direction the planter was moving, which helps reduce some of the hair-pinning problem. This approach also seems to work better when the cover crop is smaller and would probably work better with a legume that has fragile stems compared to a fairly mature winter an-

At top: The results of a roller crimper knocking down and terminating cereal rye. At bottom: spiked closing wheels being used to help close the seed furrow.

nual grass with tougher stems like cereal rye. In the Rodale organic farming system, a legume or legume mix is usually employed before corn to provide some nitrogen fixation.

I mentioned that planter setup is also important–in the 2013 planting green trial, we evaluated several different closing wheel setups (see photo on page 125). In that situation, spiked closing wheels did a better job of closing the seed furrow by helping break down the furrow wall compared to more traditional smooth-edged closing wheels, regardless of being steel or rubber. We also saw that removing trash cleaners from the planter helped, because those tended to get tangled with the big cereal rye residue, especially if hairy vetch was growing with the rye. Finally, it didn't seem to help much to use a no-till coulter in front of the planter row unit–something that surprised me.

I've since learned that many farmers who plant green in no-till situations end up removing their no-till coulters from their row crop planters. Paul Jasa, a no-till and cover crop expert at the University

A University of Missouri planter temporarily modified with a variety of closing wheels to see what worked best while planting green. Farmers can benefit from trying a few different closing wheels to evaluate what works well for their soil and cover crop situation.

of Nebraska, has pointed out that coulters reduce the total amount of down pressure a planter can place on the furrow openers. Effective planting into no-till cover-cropped fields may involve obtaining plenty of down-pressure on the furrow openers in finer-textured soils. As soil health and soil structure improve, the soil will become more mellow and furrow opening and closing easier, but Jasa says no-till transition success revolves around furrow openers successfully slicing into firm ground.

Planter settings for planting green can also be affected by the depth of seeding. Cotton farmers who need to plant shallow at one-half inch may need a different approach than someone planting corn two inches deep.

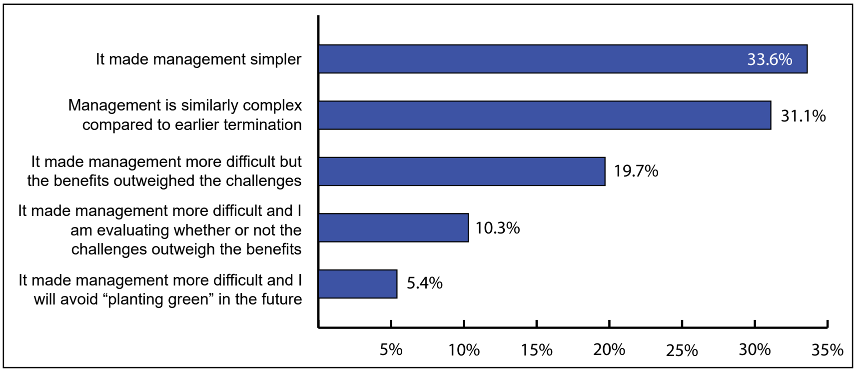
In the rest of this chapter, I'll take you through some of the main reasons planting green can be an effective strategy. While I always tell farmers just starting out with cover crops to be careful about jumping right into planting green, it's an approach to seriously consider as you gain experience. Here's an outline of some points I'll address on the benefits that can come from planting green. At the end of the chapter, I'll share a few cautions for planting green and provide a suggestion for how to test out the technique.

- Why planting green works
- Soil moisture management
- Keeping cover crop stems upright instead of matted down
- Weed control improvements
- Pest pros (and cons)
- Pollinators and beneficial insects
- Erosion stopped cold
- Soil biology enhanced
- Faster soil organic matter and soil carbon buildup
- More opportunity for spring grazing

Why planting green works

I've been intrigued by how many farmers have found that planting green works well for them, but it's certainly not all farmers. In the 2019-2020 SARE/CTIC survey that I managed, we received the following responses when we asked about farmers' experience with planting green: only 5% found planting green so difficult that they were giving up on it, but another 10% were still testing and trying to decide whether to continue; almost 85% were planning to stick with planting green, finding that it either made management easier or, at least, the benefits were worth any extra management effort.

So why does it work for farmers? I think in most cases it's a combination of factors, with several of the benefits outlined below. In my view, the two biggest benefits are better weed control and managing soil moisture in a way that leads to more timely cash crop planting. Many farmers who have been planting green for at least a few years



have told me their overall motivation is to fully maximize their cover crop benefits. In some fields, that key benefit may be better management of soil moisture; in other fields, it may be weed control. Other fields may benefit from addressing compaction or supporting pollinators by growing the cover crop longer until it starts flowering. Some farmers cite the particular goal of building up their soil organic matter and wanting to increase total cover crop growth to more quickly achieve that aim.

The bottom line is that planting green seems to work well for many experienced cover crop users. All of the ways in which cover crops contribute to cropping system resiliency and better soil health are maximized when we can let the cover crop grow for an extra 3-6 weeks in the spring. For more specifics on why planting green is beneficial, read on!

Soil moisture management

When cover crops started to become popular about a decade ago, some Risk Management Agency (federal crop insurance) staff were concerned that cover crops would use up too much moisture before the cash crop was planted and impact eventual yields. That fear proved to be overblown, although there are certainly situations where a cover crop can dry out soil too much from a short-term planting and establishment standpoint. That's why, when using overwintering cover crops, it's important to pay attention to soil moisture and monitor 10- to 14-day forecasts. If things are trending dry, it's usually a good idea to consider terminating cover crops early. Farmers in western areas may find in most years it pays to terminate early.

For farmers in higher-rainfall areas, including most of the Corn Belt, spring conditions are often too wet than too dry. In fact, a number of Midwest climatologists say much of the Corn Belt region is trending towards wetter springs. In a wet spring, planting green can really pay dividends, as was seen in 2019 when tens of millions of acres had delayed planting. That year, 68% of the farmers surveyed said that planting green helped with soil moisture management, versus only 7% who said the practice dried out the soil too much. Of the remainder, 20% said soil moisture when planting green was about the same as when terminating earlier, and only 5% said the practice left the soil too wet.

Planting green helps with too-wet soils because the actively growing cover crops continue to transpire moisture from the soil, gradually drawing down the soil moisture. The living roots also anchor the soil, making it easier to get equipment into the field for planting. This better field access is not unlike being able to walk easily across a sodded lawn after a big rain, whereas venturing onto a recently-tilled garden plot could have you sinking up to your ankles in mud.

Keeping cover crop stems upright instead of matted down

In the opening section of this chapter, I talked about our Bradford Farm evaluation of planting into an already-rolled cover crop versus a standing cover crop. There's no question that row crop planters will operate more easily through a cover crop that is alive and standing upright than a same-sized cover crop that is dying and flopping over several days after spraying. Part of the advantage comes from the lack of planter disk openers needing to slice through residue to open furrows, and part comes from avoiding the aforementioned problem of hair-pinning residue into furrows.

Some farmers have commented on how they think a standing cover crop provides a good microenvironment for establishing cash crop seedlings, protecting them from the worst of the wind and encouraging them to gain height quickly. This can help soybeans, for example, produce pods higher off the ground, so the combine header may not need to be run as close to the ground. However, the impact on pod height can vary and higher podding may not always occur. It depends on cover crop height and density, soybean variety, weather, etc.

If you've wondered whether the cover crop needs to be rolled or knocked down after planting green, the answer is no, unless it's being terminated with a roller crimper. Most planters will at least partially knock down a tall cover crop, and in any case, the cover crop stems will eventually flatten down after they die and have been hit by a few rounds of rain and wind, not to mention microbes decaying the bases of the stems.

Weed control improvements

In this era of herbicide-resistant weeds, which are an expanding problem every year, any tool that can help with weed control is a major plus. Cover crops have long been known by organic and horticulture producers as a valuable tool for weed control, and now that value is becoming clearer for commodity farmers as well. Regardless of the cropping system, allowing cover crops to grow longer helps with weed suppression.

While living, the cover crop suppresses weeds best if it is growing vigorously and shading the ground completely. Also, the more biomass a cover crop accumulates during its life cycle, the more beneficial, weed-suppressing mulch it will create after termination.

This residue mat is especially helpful during the initial weeks of cash crop growth, when the crop is particularly susceptible to weed competition. Most weed seed germination is suppressed when light is blocked by residue or heavy foliage, so the more cover crop growth there is, the fewer weeds there will be.

Pest pros (and cons)

Since the practice of planting green is relatively new, we are still learning about how the practice impacts crop pests in both positive and negative ways. “Chapter 11: Potential Issues” reviews details of what is currently known about cover crops and slugs, voles, and other pests, including references to using planting green to combat certain pest issues like slugs. Here, I’ll briefly summarize the current thinking about planting green and pests.

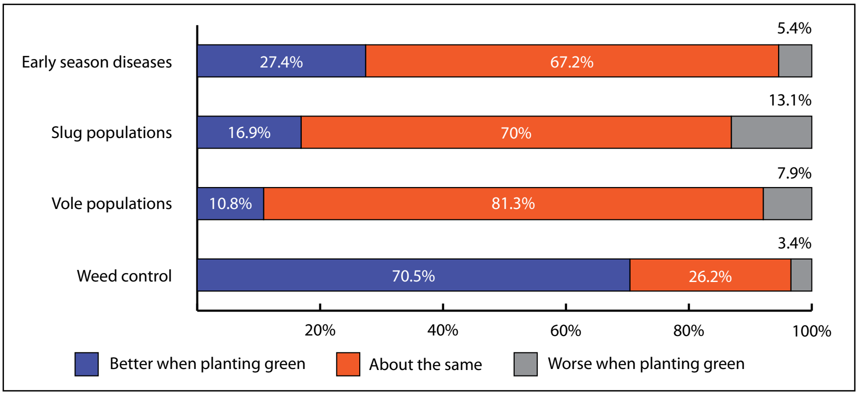
With slugs and voles, planting green seems to help in the majority of cases, although not every case. Basically, the green cover crop provides a sizable food source for the voles and slugs so that they are less likely to bother the cash crop seeds and seedlings.

Planting green may also allow the cover crop to serve as an alternative food source for insect pests that would otherwise attack an emerging cash crop. This sounds good in theory, but it’s all about timing and the pest involved. For example, if the cover crop is terminated the same day as the cash crop is planted, the cover crop might be mostly dead (turning brown) within a week, which is likely right around the time when the cash crop is emerging. This can be a problem if all the insects that had been eating the green cover crop move from the now-dead cover crop onto green, emerging cash crop seedlings. This is sometimes referred to as a “green bridge” situation, where the insect is crossing over from the green cover crop to the green cash crop seedling.

The solution is to either delay termination of the cover crop by several days (assuming the cash crop is resistant to the herbicide being sprayed or the cover crop is being terminated by roller crimper) or terminate earlier. In sum, it’s hard to say that planting green will “always” help or hurt with insect pests. The evidence so far leans to the positive side, but there have been some fields planted green that ended up with insect pest pressure. Scouting is a good idea in any crop field after planting the cash crop and definitely when planting green.

The dynamics between crop diseases and planting green are even less understood than with insects. Research to better evaluate whether planting green will increase or decrease diseases of crop seedlings is underway. From what I've read and heard to date, I think planting green is most likely to have risk of crop disease when conditions are cool and wet. Of course, cool and wet conditions are always a challenge for emerging cash crops, regardless of tillage system or cover crop use.

The greatest risk of a cover crop introducing a disease to a cash crop occurs when both types of plants are members of the same plant family, such as a grass cover crop used before corn, or certain legume cover crops before soybeans. Such planting sequences often grow successfully, but they are worth monitoring for possible disease issues. In some cases, like with insect pests, it comes down to how the timing of cover crop termination and senescence correlate with cash crop emergence. It's best if there is not a lot of dead cover crop residue right next to the emerging cash crop, especially when it's cold and wet. The goal is to keep fungal decomposing organisms or pathogens on dying cover crop plants from crossing over to the emerging cash crop.



Overall, I think the relationship between pests and planting green bears watching and farmers need to be prepared to tweak management, including the termination approach. Enough farmers are having success with planting green that I don't expect pests to be a major issue in most locations and most years, but they certainly could be an occasional problem that requires management action.

Pollinators and beneficial insects

Early-terminated cover crops that are only a few inches tall may provide a little bit of habitat for certain pollinators and beneficial insects, but much more pollinator habitat is created by allowing cover crops to reach the flowering stage, particularly with broadleaf cover crops such as clovers, vetches, peas, and rapeseed/canola. Many of the broadleaf cover crops flower relatively early in the spring, at a time when there may be few other nectar sources for pollinators. Other beneficial insects are also supported by allowing cover crops to grow for longer. The longer period of cover crop growth allows the beneficial insect populations to increase so that a sufficient number are around to help control pest insects later in the crop season.

Erosion stopped cold

Perhaps the most susceptible time for erosion in most fields is in very early spring: freeze-thaw action has loosened the soil, residue has started to decay or may have blown clear in spots, and spring rainstorms can be some of the most prolonged and intense. While an early-terminated cover crop can still reduce erosion considerably compared to having no cover crop, there's no question that the longer the cover crop grows in spring, the more it stops erosion.

When planting green, a good cover crop stand will stop almost all erosion through termination time and somewhat beyond. By the time the erosion control effectiveness of the cover crop starts to fade, the cash crop should be growing vigorously and anchoring the soil. Also, unlike in a conventional system, where rainstorms can cause gullies and erosion down the middle of crop rows in early season, the residue from a well-grown cover crop can prevent erosion between rows for the first month or more of the cash crop season.

Soil biology enhanced

One of the less-visible impacts of planting green is on soil biology. We've learned in recent years that healthy soil ecosystems are highly dependent on living roots. If we terminate a cover crop in early spring, say April 1, and then don't plant a cash crop for several weeks, it may be over two months before an active root system develops from the cash crop. If we instead keep an actively growing cover crop rooting deeply into the soil through April and potentially into May, the microbial community, including mycorrhizal fungi, will more actively provide nutrients to the young cash crop. Moreover, the much greater amount of cover crop biomass from planting green will provide more food for soil microbes during the first part of summer, again improving the health of the soil and aiding nutrient availability over the course of the season.

Faster soil organic matter and soil carbon buildup

The longer we allow a cover crop to grow before termination, the more biomass will be created. The aboveground part of the biomass is easy to see accumulating, but the belowground part–the roots–is even more important to soil organic matter buildup. Only a portion of the above-ground biomass becomes part of the soil organic matter, while most of the roots turn into active soil carbon, and some of that will later become part of the soil humus.

When planting green, especially with later-planted crops like soybeans, sorghum, or sunflowers, the amount of cover crop biomass accumulated can be several times higher than it would be with early termination. More research is needed to understand how much extra soil carbon is provided, but we know enough to say it is greater with late termination versus early. Given the importance of sequestering more carbon in the soil, the value of soil organic matter to cropping system resiliency, and the availability of soil carbon payments, it makes sense to maximize soil organic matter and carbon provided there are no significant impacts on crop profitability.

I must add that the potential of cover crops to build soil organic matter depends on soil type and climate. In hot areas with light-textured sandy soils, like the southeastern U.S. coastal plains, it can be hard to build soil organic matter, though I've heard farmers from those states say their cover crops are improving soil function in other ways.

More opportunity for spring grazing

Winter annual cover crops generally provide two windows for effective grazing: one in late fall, such as the November-December period, and one in mid-spring, after cover crop growth has resumed. If a cover crop is terminated early, when it is just a few inches high, there will be little opportunity for spring grazing. By contrast, a cover crop allowed to grow for another month can provide at least a few weeks of excellent spring forage. The grazing animals can also contribute to the success of a planting green approach by eating some of the spring cover crop biomass, making it even easier to establish the cash crop if the planter is set appropriately. Additionally, the manure, urine, and saliva from the grazing animals will stimulate soil biology.

How much cover crop growth is optimal?

While longer cover crop growth is often better, there are plenty of times where it makes sense to terminate early, particularly to plant a cash crop at the optimal time for that species and variety. On the other hand, sometimes cash crop planting can be reasonably delayed by two to four weeks to allow more cover crop growth without taking a yield loss. Such extra growth may be particularly desirable for weed control reasons or due to a combination of benefits that accrue from extra growth. If I had to generalize, I'd say letting the cover crop grow until it is starting reproductive growth (flowering) is often ideal, assuming it's not a late-flowering species. Another approach is to evaluate how much cover crop biomass is needed for the desired weed control or to provide an adequate surface mulch. For example, a meta-analysis of several cereal rye studies by Andrea Basche with the University of Nebraska found that having 3,300-3,600 pounds per acre of above-ground dry matter provided 90% weed control.

Cautions on planting green

If you are just starting out with cover crops, I'd suggest waiting a year or two before trying planting green. Or, if you are doing multiple fields of cover crops, try planting green with just one of them to gain some experience. It's important to have a plan with planting green, including the termination strategy, and be prepared to experiment with planter settings.

When planting corn into green cereal rye, it is particularly important to make management adjustments. Such an approach will likely require some modification to nitrogen fertilizer strategy to avoid having the rye tie up too much nitrogen as it decomposes, especially if the rye is turning reproductive.

Herbicide plans may need to be adjusted when planting green. The larger amount of cover crop biomass has the potential to reduce the effectiveness of some types of residual herbicides that need substantial soil contact. It may be that the cover crop can be burned down, such as with glyphosate, and then a month or so later the residual herbicide can be applied, when the cover crop has started to decompose and there is some bare soil showing. That can be better timing to address late emerging weeds in any case, as the heavy cover crop residue will likely suppress most early season weeds.

It's also critical to be able to focus on termination of the cover crop shortly after planting. Trying to rush and plant a crop field ahead of rain, and then having the field become so wet that it cannot be sprayed for cover crop termination, can lead to a potential disaster, especially if the crop is not herbicide-tolerant.

Issues can occasionally occur when planting green into tall winter cereals that are heavily pollinating: an excessive amount of pollen can accumulate on a tractor radiator screen, and if the screen is not cleaned often enough, the tractor might overheat. Reverse blowers can be installed to clear the radiator, but otherwise, it may be necessary to simply stop the tractor occasionally and brush off or blow off the radiator to prevent the tractor from overheating. Carrying a compact battery-powered leaf blower in the tractor cab is one way to quickly remove the pollen (some eye protection may be helpful in those situations).

The most important area of caution, as mentioned earlier, is monitoring soil moisture closely. If the soil is drying out and not much rain is forecast, go ahead and terminate early, even if you had hoped to plant green. Having the cover crop dry the soil out too much could really set the cash crop back in an unusually dry spring or in arid regions of the west that get less-frequent rain.

Where to use planting green and getting started

For corn and soybean farmers, I recommend making your first planting green field a field with soybeans planted green into cereal rye or another winter cereal. For this first attempt, try to plant the beans while the rye is moderately-sized–say 1-2 feet rather than 5-6 feet tall. This will allow you a chance to experience the planting green approach without having to deal with large amounts of biomass, excessive soil moisture draw down, or pollen clouds. Just be aware that rye can gain height quickly in late spring, so prioritize getting into those cover crop fields over conventional ones.

If you are farming with other crops, you may want to experiment with a few types of cover crops to see what works well for you when planting green. Try a few strips of different cover crop species in your field and see what's easy for you to plant into. There will be differences. For example, among the legume cover crops, I've found crimson clover or Austrian winter peas easier to run a planter through compared to hairy vetch, but any of them can work with the right planter setup.

Again, be ready to experiment with different options, and start with a modest, manageable amount of acreage rather than jumping into planting green on the whole farm all at once. Be ready to adjust planter settings and consider buying a few different types of closing wheels to test, including the spiked type. As you gain experience, you should find that planting green is an approach that can maximize cover crop benefits for some of your fields.

CHAPTER 9

Equipment strategies and options for managing covers

Over the last decade, there has been an explosion of new equipment, tools, and add-ons to work with cover crops and in other high-residue situations. As with every phase of agricultural advancement, the availability of efficient and effective equipment has played a big role in making progress possible; part of the modern success with cover crops is based on new varieties and new management techniques, but equipment changes have also contributed significantly to the success. In this chapter, we'll take a look at some of the newer equipment approaches impacting cover crops. We'll start out by exploring equipment for seeding cover crops, then options for terminating cover crops and planting your cash crop into covers. We'll also consider special-application equipment.

Equipment for seeding cover crops

There are a wide variety of equipment approaches being used to seed cover crops, and I expect we'll see further innovation in this area. The most reliable methods of establishing cover crops involve creating good seed-to-soil contact and proper depth placement, just as with planting any crop. Of course, these goals are best accomplished with direct-seeding tools such as grain drills and row crop planters. Although alternative seeding methods will be discussed in this chapter, we'll start with the tried-and-true methods of cover crop seeding, given the high success rate of using a drill or other planter.

Grain drills

Not everyone has a grain drill, and if you don't have access to one, skip ahead to the section "Row crop planters and when they can be an advantage." However, if you don't own a grain drill, you may find you can borrow one from a neighbor or even rent one from your local Soil and Water Conservation District office (some of these offices rent drills and some don't, but it's worth a phone call to check). Most grain drills today are well-suited to plant into residue following commodity crop harvest. Drills designed as no-till drills will do best in heavy-residue situations, given the solid weight of the drill and extra down-pressure on the row units. They are also typically equipped with coulters ahead of the row units that can slice through residue and have furrow closers better suited to no-till or high-residue situations.

Most cover crops benefit from being planted in the narrow row arrangement possible with grain drills. The narrow row spacings, such as 6-8 inches, lead to better weed suppression by the cover crop and improved soil erosion protection. If wider rows are desired, alternating rows on the drill can be blocked within the seed box.

If you are considering buying a drill to use with cover crops, evaluate whether it's worth the modest extra cost to get a second seed box. Many grain drill manufacturers offer a "small seed" box as a secondary option to the main seed box. The small seed box is normally not only smaller in volume of seed held, but also suited to smaller seeds that may need to be planted at a lower seeding rate, such as clovers or Brassicas. With two seed boxes, it's easy to plant at both a high seeding rate of a cereal such as rye and a low seeding rate of clover, radishes, or other cover crop species.

Having two seed boxes isn't required in order to use cover crop mixes, however. Nowadays, many cover crop seed companies sell pre-mixed packages of cover crops that can all go into the main seed box on a grain drill. Grain drills, unlike row crop planters, can be used with a wide variety of seed sizes without needing special seed plates or other modifications. Whether you buy pre-mixed seed or mix your own, pay attention to the seed going into the box to make sure it's uniformly mixed and not segregating out. Usually, mixes don't have too much of a problem with this, but it depends on the seeds being used. Generally, seed segregation or separation is most likely to happen when large round seed like Austrian winter peas is used with small round seed like clover or radishes.

One final thought on using traditional grain drills for cover crop seeding: a number of experienced cover crop users have told me they prefer to run a grain drill right after the combine–and I mean the

At top: Grain drills are sold by many different companies in a variety of widths. A no-till type high-capacity drill can be a good investment for establishing cover crops. At bottom: An early prototype of the 3-in-1 Penn State high clearance drill; the approach has been further refined and is now sold by Interseeder Technologies.

same day if possible, often within an hour or two. This requires an extra person in the field, but if seasonal help is available, it's something to consider. Another advantage of this method is that the stalk and leaf residue spread by the combine is still fluffy in the hours after harvest, and therefore easy to plant into. If cover crop planting is not begun until some days later, the crop residue will be more packed down, especially if a rain has occurred in the meantime.

High-clearance drills for interseeding

A relatively new equipment option among grain drills for cover crop planting is high-clearance drills, such as the one sold by Interseeder Technologies. Typically, these high-clearance drills are designed to interseed cover crops into a standing cash crop such as knee-high corn. The idea is to start the cover crop as early as possible. Normally the cover crop emerges by mid-summer, but then stops growing in the heavy shade of the cash crop canopy until early fall, when the canopy opens up. Based on research to date, the interseeded cover crop does not normally create a yield drag on the commodity crop. However, any herbicide programs in use may need to be adjusted to allow for the interseeded cover crop.

The high-clearance drill approach that was developed by researchers at Penn State University, and is reflected in the products sold by Interseeder Technologies, can also spread liquid fertilizer and/or an herbicide or pesticide spray at the same time as seeding the cover crop. This allows making one trip over the field and accomplishing up to three tasks at the same time, making it a great approach for labor efficiency.

Row crop planters and when they can be an advantage

Whereas a lot of older grain drills are only 10-15 feet wide, many of today's row crop planters are 30-40 feet wide or more (although 30-foot-wide drills can be purchased as well). Some row crop planters can also operate at a higher speed than grain drills. This extra ground-covering ability means that row crop planters provide a significant advantage when planting large acreages of cover crops. Farmers have also told me they feel they can cut back on their cover crop seeding rate with a row crop planter, because the more precise seed placement and depth control creates better stands from fewer seeds.

It's best if the row crop planter can plant rows narrower than 30 inches for erosion control purposes. However, some farmers have reported satisfactory results with wider row spacings for covers, especially when planting on a contour with any slopes. Besides the fact that better ground cover is provided by a split-row planter that can plant on 15-inch centers or similar, I like that row crop planters provide some flexibility in seeding arrangement. Assuming individual seed boxes are being used on each row or twin bulk seed boxes are being used, it's possible to plant alternating rows of two different cover crops.

The most common method of planting alternating rows of two cover crop species is to plant one of the rows with a crop that will winterkill–typically a Brassica such as radishes–and any kind of over-wintering cover crop in the other row. The following spring,

Bio strip-till type arrangement with alternating rows of radishes and a winter cereal.

Broadcast seeding pros and cons

Some farmers simply broadcast cover crop seed, and this approach is particularly common for first-time users of cover crops who hire out the spreading or need to do it quickly themselves. Broadcast seeding can work well if the seed makes good contact with the soil and adequate moisture is present. Usually, it works best if there is rain within a week or two after broadcast seeding. Seed that sits on top of residue and/or remains dry for a prolonged period is unlikely to ever establish. Also, the longer the seed sits on the ground, the more subject it will be to birds, crickets, other insects, small mammals, or even nightcrawler worms eating the seeds.

Some farmers have reported that their best results with broadcast seeding occur when it is done the same day as harvesting, so that the seed has a better chance of making contact with the soil while the residue is still "fluffed up" from the combine and before the residue is matted down by rain and time.

you can use GPS to plant corn in the same strip the radish plant was in. The radish plant–assuming it achieved adequate fall growth–will have formed a rosette of leaves about 4-6 inches in diameter that crowds out winter annual weeds. The rosette of leaves will die in early winter, then decompose by corn planting time, often accelerating the decomposition of underlying residue from the previous crop. This is because radish leaves are high in nitrogen compared to most commodity crop residue, so the combination of radish leaves with crop residue creates a more favorable C:N ratio for microbes to work with, speeding their breakdown of residue. This process creates a bare or nearly bare strip of soil to plant corn into the next spring. Some have called this approach "bio strip-till." (See photo on the previous page.)

A potential downside of row crop planters is that the settings are seed-size-dependent, meaning it's hard to use mixes of cover crops with different seed sizes. On some planters, a seed cup can be used to handle multiple seed sizes. Specialized seed plates normally limit use to similarly-sized seeds. Use of seeding plates can also involve buying a few sizes of plates if various cover crops are to be planted. This is not a large expense, but one that involves a little extra labor to change plates or change a seed drum, if using an air planter. I've had a few farmers tell me they prefer not to use a row-crop planter for cover crop seeding to avoid extra wear on the planter.

Broadcast seeding with fertilizer spreaders

One of the most common methods of cover crop seeding on farms of all sizes is to use some type of broadcast fertilizer spreader, such as a power take-off mounted spreader on the back of a tractor, an electric-powered spreader on an all-terrain vehicle (for smaller acreages), pull-type fertilizer spreaders, or a large truck-type spreader such as the ones used by fertilizer dealers. Regardless of the size of the rig, depending on species involved, the cover crop seed may not broadcast or throw as far as fertilizer pellets do, so be sure to check the seeding width and take wind patterns into account when determining the broadcasting pattern. Also, with mixes of different cover crop species, some lighter seed may not throw as far as heavier seed, so some overlap on the seed spreading pattern may be desirable.

Granular fertilizer can be mixed with cover crop seed and broadcast at the same time. Again, pay attention to the pattern of distribution; the fertilizer may throw farther than the cover crop seed, so be sure to set an application width that ensures complete coverage with the seed. Avoid storing seed that has been mixed with fertilizer. The fertilizers function as salts that draw moisture from the cover crop seed, drying out the seeds if left mixed together for too long and effectively ending the viability of some or many of the seeds. It's best to broadcast a mix of fertilizer and seed within a few hours of mixing.

Broadcast seeding with high-clearance sprayers

A relatively new trend in cover crop seeding is to use high-clearance sprayers modified for spreading seed. These high-clearance sprayers, designed to navigate through full-height corn in mid-season, can also comfortably move through corn in late August or early September, which can give cover crops a head start before harvest. Some companies have started selling modification kits for their high-clearance sprayers. In other cases, farmers have made their own custom modifications. In all cases, the liquid sprayer box is removed and replaced with a seed box. An air blower is attached to blow seeds through long tubes that are distributed along a spreader boom. Depending on the seed to be spread and the strength of the blower, seed booms are 60-120 feet wide. The seed distribution tubes blow the seed onto a metal diverter that spreads it over the width of the row. Typically, the diverters are on drop tubes that run about 3-4 feet above the ground. Depending on set-up, high-clearance cover crop seeders may be able to seed up to 500 acres per day in optimal conditions.

The advantages of high-clearance seeders over aerial application include the following:

- More even distribution of seed
- Ability to spread seed on days that are too windy for aerial seeding
- Keeps seed on your field and out of your neighbors' fields
- Creates custom seeding opportunities for farmers
- Makes use of existing equipment that can be run by a farmer or ag retailer

The last point is a particularly noteworthy one in the context of ag retailers. The late-summer and early-fall time period is a relatively slow one for many ag retailers, with summer spraying over and fall fertilizer applications not yet begun. They therefore have a labor capacity during this time period that is often underutilized and high-clearance sprayers sitting idle. Why not take this opportunity to spread cover crop seed?

If the local ag retailers are not doing custom cover crop seeding, there can be a niche opportunity for farmers who want to adapt their own high-clearance spray rig (or buy one) and do some cover crop seeding. A typical modification kit for a high-clearance sprayer costs roughly $50,000 and takes about a half-day to install. This price sounds steep, but when you consider that aerial seeding can cost $12-$15 per acre (or more for small remote fields) and the modification kit can do hundreds of acres per day, in one season or two at most, the kit can pay for itself.

Aerial seeding

In 2015, about 16% of farmers responding to the SARE/CTIC National Cover Crop Survey indicated that they were primarily using aerial seeding. Over the last several years, many aerial applicators have gained experience with cover crop seeding. It's worth asking potential aerial applicators about how much they have worked with cover crops, because it involves some different strategies than other field operations they may be used to. The number-one advantage of aerial application is that it is possible to do when field conditions are too wet for ground operations. Since soil moisture is critical for seed establishment, this can be a significant advantage of having seed flown on, assuming it can be done in a timely fashion right after or before a rainstorm. Of course, hiring an aerial applicator also eliminates the time demand of having to plant cover crops.

Besides the ability to fly seed on when ground equipment would get stuck in the mud, aerial application allows cover crops to be seeded while cash crops are still in the field. Just as with high-clearance seeding rigs, seeding into standing corn should be done during the window after corn leaves have started to turn color and before harvest. Flying seeds onto soybeans successfully is more challenging, as it requires working within a narrower time window of about a week, after the leaves start yellowing but before the leaves have dropped. If you fly seed on too early in corn or soybeans, the heavy shade (particularly in soybeans) will likely prevent growth. If cover crop seeds are flown on after soybean leaves have dropped, the dense mat of soybean leaves on the ground will prevent seed-to-soil contact by the cover crop seed, making establishment unlikely unless a heavy rain can wash the seed off the leaves.

Another consideration with aerial seeding is the type of cover crop you are going to use. Some cover crop seeds have been found to work reasonably well with aerial application. Brassicas (such as rad-

At top: The Hagie Montag Cover Crop Interseeder being used in corn prior to harvest. At bottom: Cover crop seed being flown on into soybeans at the key time of leaf yellowing and before leaf drop.

ishes, turnips, or canola) work well because they are seeded at a low rate (thus more acres can be flown on per plane load) and they have a dense, round seed that broadcasts uniformly and establishes well. Cereal rye and annual ryegrass work reasonably well from a physical distribution standpoint and for broadcast establishment. Large seeds such as Austrian winter peas are difficult to broadcast-establish, and lighter-weight seeds such as oats or sunflowers can be difficult to spread uniformly by airplane.

Broadcast seeding while combining

Being mechanical innovators, some farmers latched onto the idea of rigging up a seed blower to their combine. Gandy sells seed blower kits of various sizes specifically for mounting on a combine header. This offers the advantage of applying seed simultaneously with harvesting, avoiding a separate trip over the field and allowing more growing time for the cover crop.

The normal approach to this method is to blow the cover crop seed onto the ground through tubes and diverters directly underneath the combine head. In my opinion, this is a strength of the approach because it puts the seed in contact with bare soil before all the leaves, stalks and chaff are blown out the back of the combine. Instead of seed being broadcast later on top of that residue, it is blanketed by the residue, maintaining the seed moisture. As long as the residue is not too thick and some soil moisture is available (at planting or soon after), the seed has a decent chance of establishing. Having a good stalk chopper on the combine that distributes residue evenly will enhance the odds of success with this approach.

However, I've heard some farmers who tried this approach say that they are not keen on stopping the combine to get out and load cover crop seed. Thus, this system will probably work best on a farm where there is a person driving a grain cart or grain truck who can help out with the cover crop seed loading, to minimize downtime for the combine operator.

A combine modified with a Gandy air seeder that blows seed on ground underneath the corn head. Demonstration on Steve Groff's farm.

Broadcasting with incorporation

In the 2022-2023 SARE/CTIC National Cover Crop Survey, about 44% of the responding farmers said using a grain drill was their primary seeding method, while 32% primarily broadcast with ground methods and 13% by aerial seeding (the remainder used a precision row crop planter or other method). When broadcasting cover crops, some farmers do it with an air seeder attached to a tillage tool, with vertical tillage tools being a common technique.

Seeding with a vertical tillage tool

Vertical tillage tools, which look like traditional disks except with flat blades, have become a popular approach for "light" tillage in the fall, particularly on corn ground following harvest. For farmers who are already making a trip over the field to do vertical tillage, it is possible to seed cover crops at the same time with the vertical tillage machine; it just involves putting an air seeder box and distribution tubes onto the vertical tillage unit. Valmar and Gandy are two of the companies that make seeding kits compatible with vertical tillage units. Normally, the seed is blown out at the front of the unit, allowing incorporation of the seed as the tillage unit goes over the ground.

On the plus side, this is a good labor-saving approach and generally achieves a higher percentage of cover crop seed establishment than just broadcasting. There are two potential drawbacks, however. One is that the depth of seeding is difficult to control, unlike with a drill or row crop planter; some seed will stay on the surface and some will be buried too deep. This is more of a problem for shallow-seeded cover crops like radishes and annual ryegrass than for covers that can tolerate deeper seeding, like cereal rye, wheat, or oats. The other potential issue is the timing of the operation. If vertical tillage is done within a few days of harvest, it can be a workable approach for cover crop establishment, particularly for cereal rye or other cereals. However, if vertical tillage doesn't start until every last field is harvested, then some of the seeding may end up happening much later than desired. If possible, when using this approach, try to have someone lined up to run the vertical tillage unit through the field either right behind the combine or within a couple of days of combining.

Other incorporation methods in combination with broadcast seeding

Besides vertical tillage, other shallow tillage tools can be used for cover crop seeding. Sometimes traditional disks are used, but they have the drawback of throwing more soil than a vertical tillage unit, potentially burying some of the cover crop seed too deep. A field cultivator could be used, but those are rarely employed in the fall when cover crop seeding is typically done. Rolling harrows set up with an air seeder are another option (see bottom photo on page 153). Some farmers have used aeration-type fall tillage tools that leave most residue in place but provide some soil disturbance action that can further incorporate cover crop seed.

Equipment for terminating cover crops

The most common ways to terminate a cover crop are to let winter do the job (using winter-killed species of covers) or to terminate the covers through use of a spring burn-down herbicide. In either case, no extra labor or equipment is needed, unless spring burn-down is not a normal practice for control of winter annual weeds.

For less-common termination approaches, a variety of termination equipment has emerged, and more will likely be developed in the future. Below I will briefly discuss terminating your cover crops with a variety of equipment options, including lightweight spray rigs, roller crimpers, or mowing. More detailed information on termination strategies is in the two preceding chapters (Chapters 7 and 8).

Lightweight spray rigs

As cover crop acreage began to expand over the last 10-15 years, a few companies started marketing light-weight spray rigs that could cover a substantial number of acres simply using a large ATV with flotation tires. The idea was that it might be difficult to get across a wet field, especially one just thawing out, early enough in the spring to terminate a cover crop ahead of corn. Some of these rigs had booms that could cover a 60-foot-or-wider width, and I'm sure a number of these are in use, particularly in areas with colder, wetter springs. However, my impression is that more farmers are terminating cover crops later than was typical a decade ago, and so termination may be more easily done by larger spray rigs, including ones run by ag retailers.

Roller crimpers or just rolling cover crops

Probably one of the most talked about innovations in modern cover crop management has been the use of roller crimpers. Steve Groff, a Pennsylvania farmer and widely-known cover crop innovator and expert, was perhaps the first to develop and use a roller crimper for cover crop termination. Around the same time, the Rodale Research Center started experimenting with them, also in Pennsylvania. As mentioned in Chapter 8, I heard a presentation by Jeff Moyer of the Rodale Research Center in 2008 about their success terminating cover crops with a roller crimper mounted on the front of a tractor, while simultaneously pulling a no-till planter behind the tractor. I was intrigued by the approach at the time and encouraged our University of Missouri agronomy farm manager at the time, Tim Rein-

At top: Kuhn vertical tillage tool with optional cover crop air seeder. Several companies have similar options. At bottom: A rolling harrow set up with a cover crop air seeder.

bott, to obtain a roller crimper, which he did. Since then, hundreds of farmers and researchers have experimented with the best ways to use roller crimpers. While the total acreage managed with roller crimpers remains modest, for organic no-till and other special circumstances, they are an invaluable tool.

The biggest limitation of roller crimpers is the speed of operation. A typical unit from I & J Manufacturing is only 10 or 15 feet wide, although they can custom-make wider, folding units. Howard G. Buffett had a custom unit made for a 60-foot John Deere folding toolbar. I have seen this unit and it can certainly cover a lot of acres, but its width is not common.

Another limitation of roller crimpers is their effectiveness at completely killing the covers. They work best when the ground is not too wet; otherwise, the cover crop stems may simply be pressed into the mud and not crimped enough to terminate growth. Also, if the cover crop biomass is lush, the roller crimper can fail to totally crimp all the stems in a several-inch layer of fresh residue. Sometimes a second pass is needed in such situations. As with mowing a cov-

A roller crimper being used to terminate growth of cereal rye.

er, most species are far more easily killed by a roller crimper once they've reached their reproductive stage. The majority of cover crops are usually easier to terminate at a vegetative stage by spraying than crimping.

A tip for those trying to do no-till with cover crops is to roller crimp after planting rather than before (especially for organic fields). Researchers and farmers have learned that planting into already-rolled cover crops has two drawbacks: one is pinning the residue into the furrow, and the other is that the action of planter openers creates a zone of tillage that exposes weeds to sunlight. If rolling is done after planting, this furrow area will be covered with residue, reducing weed emergence but not hindering vigorous cash crops like corn and soybeans. For those who are rolling before planting, it's best to plant in the same direction as the cover crop was rolled. Also, it's a good idea to experiment with different types of closing wheels to produce optimal furrow closure.

The design idea behind a roller crimper is that the metal crimping edges of angular steel welded onto the roller will break the vascular tissue (xylem and phloem) when pressed with force into the cover crop stems, effectively killing the plant. This provides more effective termination than just using a plain, round roller does. However, some farmers, particularly in the southern U.S., have successfully terminated selected covers such as cereal rye with plain rollers or cultipackers. This usually involves waiting until the rye or other cereal is heading out, at which time it's easier to break the stems during the rolling action. However, if the cover crop stems are rolled down without breaking, they will likely stay alive.

Mowing cover crops for termination

A sure-fire way to break cover crop stems is to use a mower. I learned the hard way back in the early 1990s that mowing too early offers little benefit, much like mowing your lawn and watching it regrow. At that time, I tested several cover crops and terminated them with either tillage, spraying, or mowing. The mowing worked well on crimson clover that had started to bloom and on the rye that was starting to head, but the hairy vetch was not yet flowering and immediately started to regrow after mowing. Thus, I advise waiting until after flowering is well under way before trying to terminate a cover crop by mowing alone.

One other tip for mower termination of covers is that a flail mower can do a more even job of chopping up and spreading the residue. Flail mowers are a particularly good idea in vegetable fields or other horticulture operations where other workers may be around. Flail mowers are much less likely to throw stones or other debris than rotary mowers. Other types of mowers can be used for terminating cover crops as long as safety is taken into consideration.

Terminating cover crops with tillage

I don't recommend terminating cover crops with tillage, both for soil health reasons and to avoid creating a clumpy mess that is hard to plant into. When a cover crop is terminated at a small size, it's possible that a decent seedbed can be prepared with light tillage after the cover crop is grown. However, when there are several tons of biomass per acre, such as 5-foot-tall rye or a dense cover crop mix, I've found that tilling such a large amount of biomass leads to major seedbed preparation challenges. The cover crops can be terminated easily enough, but it might take multiple tillage passes over multiple days with some time for drying in-between to get to the point where the field is ready for a planter to be run through it (and that's assuming there's a run of dry weather at the right time).

The exception to the above advice on tillage termination is for smaller vegetable or home garden operations, or other situations where spray termination is being avoided. In these situations, the extra labor is generally not an issue that would prevent making an extra pass or two over the planting area. If a significant amount of cover crop biomass is present in a home garden or small vegetable plot, I've often mowed first to chop up the residue and then rototilled it. The small pieces of residue usually incorporate into the soil well with the rototiller, especially if allowed to dry for a day or two before tilling. Just keep in mind that each tillage pass has a potentially negative effect on soil health and leaves the soil more subject to erosion.

Equipment modifications for planting in cover crop residue

You might think that a no-till drill or no-till row crop planter is all you need for planting into cover crop residue, and in many situations you would be right, particularly if cover crop growth is minimal at planting time. However, in situations with higher amounts of cover crop residue, additional modifications may improve the success of your cash crop planting.

One thing I've heard from a few farmers is that they found it was actually beneficial to remove the no-till coulters from their planter when planting into cover crop residue. Those farmers said the coulters were pinning too much cover crop residue into the furrow area. This might not always be the case, but it is something to watch for. Likewise, trash-clearers or row-cleaners that are effective for loose corn stalk residue might create problems with living, anchored cover crop plants, leading to tangling and pulling of the covers. The row-cleaners might have to be lifted up or taken off the planter in these circumstances.

Generally, a double-disk opener with reasonably sharp blades can function well in cover crop residue. I've heard of an occasional situation where a farmer found a serrated type of disk opener performed better for their soil and residue situation to slice through the residue.

Some farmers have found it helpful to switch to different types of closing wheels when working with high-residue covers. Quite often, some type of spiked or knobby closing wheel will perform better than a smooth-edged rubber or steel closing wheel, but it depends on soil type and other conditions. I encourage you to buy a few different closing wheels and experiment to see what works best for you in various situations.

Equipment modifications for using cover crops with manure and/or fall fertilizers

It is possible to combine the cover crop seeding with liquid manure application. The cover crop seed can be mixed into a manure slurry.

The moisture and nutrients of the slurry can help the cover crop seed sprout well; often some light incorporation may be helpful, other times surface application might suffice. Here are a few tips to consider when using this approach:

- Be sure to vigorously agitate the manure solution to keep the cover crop seed well-suspended–otherwise it may start to settle in the tank.
- A recirculating pump can help keep the seed in suspension and avoid clogging.
- Light incorporation of the manure and seed can help to both establish the cover crop and reduce runoff of manure, if the operation is no-till.

The downside of seeding the cover crops with the manure application is that the best timing for each may not coincide. The cover crops should be planted as early as possible after harvest, if not before, whereas colder weather (such as in November) may be optimal for the manure application. In cases where the cover crop needs to be seeded earlier than the manure application, I recommend a review of the manure injection equipment to evaluate it for amount of ground disturbance. If the injection knives or blades disturb more than about 20% of the soil surface, they will do a large amount of damage to the planted cover crop, so a less disruptive injection knife may need to be installed. The exception is in cases where the knifed zone is spaced out to where corn rows will be planted the next spring, effectively creating a strip-till situation.

Having a growing cover crop near the time of manure application can help tie up some of the manure nutrients in biological form, reducing runoff or other loss of the manure nutrient value. Similarly, fall cover crops can help benefit fall nutrient applications.

As with manure injection, some thought should be given to the method used for fall application of fertilizers, especially if they are being incorporated, such as anhydrous ammonia. Anhydrous knives normally don't disturb a high percentage of soil, so they can be compatible with a cover crop; in fact, the cover crop can tie up some of the nitrogen, acting as a biological nitrification inhibitor and potentially reducing the need for a chemical nitrification inhibitor. Still, it's best to review your plan for fall fertilization to make sure it is compatible with survival of the cover crop you are investing in.

Looking ahead on future equipment development supporting cover crop use

Anyone who goes to farm machinery shows or reads farm magazines knows that equipment is continually redesigned. There is no doubt further customization and modifications will lead to improvements in cover-crop-related equipment. One of the incremental improvements I am hoping to see is the development of more high-clearance seeding equipment that can incorporate the cover crop seed rather than simply broadcasting it. I discussed the use of high-clearance drills earlier, but those are currently limited to corn that is about two feet tall; I'm interested in seeing development of equipment that can navigate through full height corn while performing some incorporation. Hagie actually developed such a machine using a modified version of their high-clearance nitrogen toolbar. They experiment with rolling-basket-type units and simpler roller-press wheels to incorporate the cover crop seed. The machine showed some promise of having improved performance for seed establishment over a high-clearance broadcast rig, but they told me the limitation was the speed of seeding; the toolbar is considerably narrower than their modified spray rigs. Future equipment might accommodate high-speed seeding with light incorporation at the end of August. That would be a plus for establishing covers earlier.

An alternative approach to planting the cover crop seeds into a standing cash crop field is to use small, precision-guided robotic units. A company out of Minnesota, Rowbot, was the first to envision such a system. I got to see their founder, Kent Cavendar-Bares, operate a prototype unit at a field day in 2014 and was quite impressed. Kent grew up on a farm in Minnesota and went on to complete advanced technical training while doing a Ph.D. at MIT. I hope his vision receives further evaluation and trialing going forward. He envisions a fleet of small, GPS-guided, diesel-powered robots spreading fertilizer, sprays, or cover crop seed and operating 24/7 to cover fields with minimal labor. You can see videos of the Rowbot in action if you do an internet search for the product by name. Other companies have also started to research this approach of having small, autonomous robots go through the field.

Another hot area besides robots is the emergence of drone use for agriculture. So far, drone use has been focused on aerial survey and photography and, in some high-value crops, spraying of pesticides. Might we see drones used in conjunction with cover crop and soil health goals to identify areas of the field that need adjusted management, not unlike other aspects of precision agriculture? Drones don't yet have the capacity to seed large acreages of cover crops, but they already offer potential for helping us evaluate field variation. New generations of drones may work well to broadcast selected cover crops that have a low seeding rate, like radishes or other Brassicas.

An early prototype of the Rowbot interrow diesel-powered unit. Newer models have tracks instead of wheels and can spread cover crops or fertilizer in an autonomous fashion between rows.

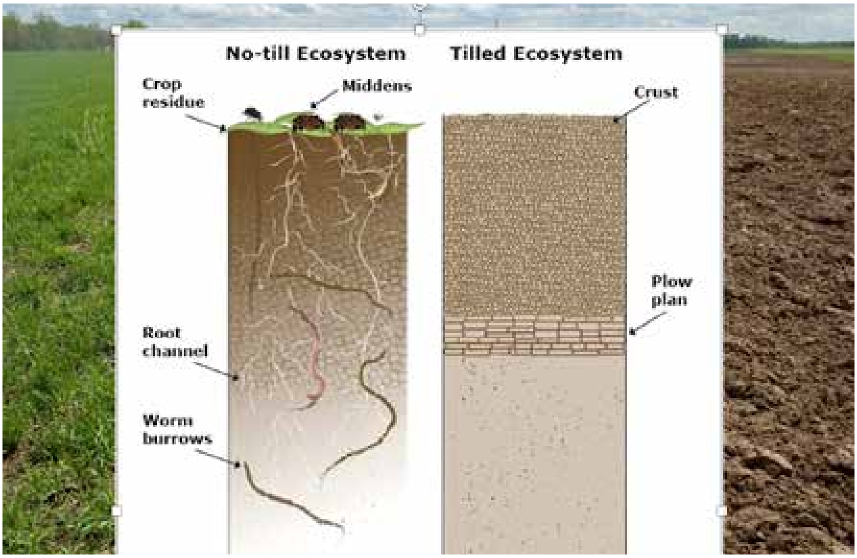
CHAPTER 10

Combining cover crops with other field practices to further improve soil health and resiliency

While the focus of this book is on cover crops, there is no doubt that there are several other practices that can build soil health, and most of these can be used very effectively in combination with cover crops. Many conventional farmers who adopt cover crops start seeing the benefits of improved soil health and ask "What else can I do to improve my soil health and cropping system resiliency?" Many find themselves reducing tillage and start experimenting with no-till. Others add grazing, either with their own livestock or by leasing part of their cover-cropped ground to a neighbor. Buffer strips start to become more economically viable with grazing as part of the land management, and diversified crop rotations may also be of interest. Each of these practices and its relationship with cover crops is discussed below. Combinations of these practices can boost overall conservation progress on your farm and produce fields that are more resilient to droughts, downpours, and other challenging conditions.

Minimizing soil disturbance with no-till or strip-till

My first exposure to no-till was a neighbor about a mile from our home farm who switched to no-till in the mid-1970s when I was in my teens. I never got to hear why that neighbor made the change, but I did hear plenty from my dad about how skeptical he was of no-till, with frequent negative comments about how "trashy" the neighbor's fields looked. My dad subscribed to the school of thought, as did so many farmers of that era, that you were a good farmer if you had clean-tilled fields and you got your tillage done early. Ironically, 20 years later as my dad was retiring from farming in the mid-1990s, he told me that if he had planned to farm for another five years, he would have switched to no-till. His comment surprised me, because no-till was still uncommon in central Illinois at that time. It was a good lesson in how accepting change can take time, but my dad had started to see the benefits our neighbor was getting from no-till.



This illustration shows how tillage degrades soil structure and disrupts the macropores that are critical to rainfall infiltration and root growth. Photo shows cover crop to left and tillage to right. Illustration from USDA-NRCS, photo by author.

In the 1980s I got some first-hand experience with no-till in a large, multi-location corn study in Minnesota that involved several tillage approaches in combination with different nitrogen rates. That work led me to develop a prototype software tool for helping farmers select a conservation tillage system as part of my PhD research. As part of that work, I consulted with some tillage experts on factors to consider when deciding on no-till versus other options. I learned there are a lot of factors that come into play when considering a switch in tillage systems.

When I moved to Missouri in 1989 to become an agronomy faculty member at the University of Missouri, I found that many farmers had adopted no-till to address erosion issues on sloping Missouri fields. However, at our university agronomy farm, nearly all of the crop research was done in tilled systems. I started to experiment with no-till and cover crops in the early 1990s but did not become a whole-hearted advocate of no-till until I later learned the importance of minimal soil disturbance for maintaining soil biology. I also learned how no-till supports development of improved aggregate soil structure and macropores (vertical channels in the soil). The photo on page 162 shows how the tunnels from earthworms and decaying plant roots provide macropores that allow rainfall to quickly infiltrate the soil. The better soil structure in undisturbed fields leads to better water holding capacity and also contributes to increased root growth.

Another key aspect of no-till for soil health is the impact of tillage on mycorrhizal fungi. These fungi play an important role in helping crop roots access more nutrients in the soil and can aid with water uptake. Tillage destroys fungal hyphae and leads to a reduced presence of beneficial mycorrhizal fungi in the soil.

Tillage passes also cause loss of soil moisture. According to Jerry Hatfield, former director of the USDA-ARS National Center for Agriculture and Environment, each spring tillage operation causes a loss of moisture equivalent to half an inch of rainfall (No-till Farmer, 2013).

Many farmers have seen rainfall simulator comparisons of no-till cover crop fields with tilled soils. As the photos on the following page illustrate, more rainfall soaks into soil that is no-till and cover-cropped than soil that is tilled. This not only helps during dry periods, providing critical moisture to crop roots, but it also helps reduce loss of topsoil and expensive fertilizers through runoff from the field.

From a profit and time standpoint, no-till is considered a superior system because it requires fewer trips over the field and reduced machinery and diesel fuel expenses, as well as lower machinery maintenance and storage costs. Many no-till farmers feel they can more comfortably farm more land in this system and, when including cover crops, are able to plant or harvest sooner following rainfall.

Some conventional farmers have hesitated to try no-till for fear that spring planting will be delayed. They worry that soils will stay too cold and wet in no-till compared to fall-tilled fields that may warm up faster with spring sunshine. What's important to know is that cover crops can help overcome these no-till concerns. Cover crops in a no-till system are stimulating soil biology, and between the

At top: A rainfall simulator, with tilled soil (second pan from left) showing most of the rainfall running off the soil into the front jar, while the cover-cropped soil allowed the rain to infiltrate into the soil and drain into the back jar underneath the soil tray. At bottom: the two trays of soil flipped over after an inch of simulated rain from an overhead sprinkler. The tilled soil in the foreground sealed shut after the sprinkler started running, preventing the simulated rainfall from soaking through, while the macropores in the no-till cover crop soil allowed the water to quickly soak into the soil.

living covers and more active soil biology, soils with cover crops tend to stay warmer than soils that are no-tilled without cover crops. The cover crops can also draw down excess moisture in the spring, increasing the odds of planting earlier (if it's a dry spring, however, early termination of the cover crop may be prudent).

The increased rainfall infiltration and better soil structure in a cover-cropped no-till system allow soils to drain and provide an improved surface for field operations. If a picture is worth a thousand words, the photo below tells a powerful story of how cover crops and no-till can really help with planting in a wet spring. Conventionally tilled soils, especially in flat fields, are more likely to seal shut during the rain and end up with standing water. The lack of soil structure makes it impossible to drive a tractor across these fields until the surface dries out, and even then, subsurface moisture may lead to tractors becoming stuck. Good soil structure with living roots allows field operations to resume more quickly in many situations after a big rainfall event, not unlike walking across sod is easier than walking across bare soil after a big rain.

A cover-cropped no-till field can provide a beneficial residue layer in the first half of the summer that will keep your soil from getting baked by the sun. Most soil microbes fare best in moderate soil temperatures, and crop roots are less stressed under residue than in overheated bare soil. The residue also helps reduce soil erosion and runoff of soil nutrients until the summer crop canopies over. Most of the cover crop residue will decompose on healthy soils as the summer proceeds due to the action of soil microbes and earthworms, but that decomposition process with residue and cover crop roots provides another benefit by contributing to your soil organic matter.

Switching from conventional tillage to no-till can also have a significant impact on weed control and management. In the past, many herbicides required some form of light tillage incorporation to take full effect. This is no longer the case with many of the currently used herbicides, including glyphosate. Avoiding disturbance of the soil can reduce germination of many weed seeds, while having a heavy residue layer will further reduce germination of weeds that need exposure to light to germinate. A counterpoint to no-till weed control is

The long-term no-till field that's been cover cropped on the left has excellent rainfall infiltration compared to the field that's been conventionally tilled without cover crops on the right (same soil type). In this situation, you can guess which field will be planted first. This Oklahoma photo was taken in the spring of 2019, when prolonged spring rains delayed planting by several weeks on tens of millions of acres. Photo courtesy of Russ Jackson.

that certain perennial weeds that can be killed by tillage may be more likely to occur in some no-till fields. However, the overall weed control benefits of no-till combined with cover crops are substantial and another reason to consider using these practices in combination. Cover crops combined with no-till provide further weed suppression benefits compared to no-till alone. This is due to early shading of weeds provided by cover crops and the additional residue layer. Additionally, if cereal rye is the cover crop, its allelopathic effects can reduce growth of small-seeded annual broadleaves.

Strip-till

For farmers who hesitate to convert to a full no-till system, the most widely accepted alternative is strip-till. In some states, there are thousands of farmers employing the strip-till system. Equipment manufacturers have come up with a variety of strip-till equipment. The basic concept is that soil disturbance is minimized by doing only shallow tillage in a narrow strip where the cash crop seed will be planted, particularly corn or soybeans. Farmers using this system hope to create a warmer seedbed in the tilled strip. The narrow zone of tillage also allows for some incorporation of fertilizer. Tilled strips are typically 6-12 inches wide. Most often, the tillage strips are prepared after harvest in the fall, so that the soil can be warmed and ready for planting in the spring. However, if wet fall weather or other factors prevent fall tilling of strips, they can be tilled in the spring.

With the advent of autosteer and precision tractor guidance systems, planting in the same precise strips each year allows the interrow areas to remain in a continuous no-till state. This is conducive to the formation of desirable macropores and soil structure in the interrow areas, which enhances overall rooting and rainfall infiltration.

For farmers trying to decide whether no-till or strip-till can work for them, my advice is to visit with other farmers in your area who are experienced with these systems to see what is working well for them. You will generally find that most of these practitioners are more than willing to share what they have learned and help ease your transition to improved soil health management.

No-tilled field with cereal rye cover crop providing a nice protective residue mat over the soil.

At top: Strip-till soybeans planted into corn residue. Photo courtesy of Jodi Delong-Hughes, University of Minnesota. At bottom: Planter configured to create narrow tilled strips while planting into cover crop residue. Photo courtesy of Paul Jasa, University of Nebraska.

Buffer strips

Along with cover crops, one of the newer emphasis areas in conservation circles is planting buffer strips either on field edges or along contours across a sloping field. While the practice has been around for decades, an increased understanding of how such strips can help with pollinators, beneficial insects, songbirds, and other wildlife has stimulated their use. The benefits extend further, to erosion control and reducing runoff of fertilizers and pesticides from fields. Iowa State University ag scientists have done in-depth studies using prairie strips planted on the contour of sloping corn and soybean fields. They found that planting 10% of the field to prairie strips could reduce soil loss by 95%, runoff of phosphorus by 90%, and runoff of nitrogen by 85%. Diversified buffer strip plantings can be done on top of terraces or as an alternative to terracing a sloping field. On level or nearly-level fields, such plantings can be used along field borders, waterways, or drainage ditches. Buffer strips can also be done as riparian plantings along creeks and ponds.

Buffer strips are most often perennial herbaceous plants, ideally including a mix of native stiff-stemmed prairie grasses with broadleaf plants (forbs). The grasses play an anchoring role to stop erosion and the stiff stems reduce the speed of water running over the soil surface, filtering out some sediments, fertilizers, and pesticides. The forbs provide food and habitat for pollinators and other beneficial insects. The strips provide food sources and cover for wildlife. In riparian buffers, woody plants are often introduced into the mix – either native shrubs if in a narrow corridor or native trees where a wider planting can be made.

While most farmers and landowners can understand the potential value of such buffer strips, the challenge of planting them and the prospect of taking land out of production remain disincentives. Some government incentive programs can help with the costs, such as the USDA Conservation Reserve Program (CRP), which now allows long-term payments for setting aside such strips instead of taking whole fields out of production. A way to actually generate income from buffer strips is to plant cover crops in between the strips and then graze the entire area (though young trees and shrubs planted in riparian areas may need to be fenced off). While it wouldn't be economical to graze just a narrow strip, by having living vegetation that can be grazed in late fall or early spring over the entire field, the whole system becomes much more practical.

For those concerned about how to manage spraying herbicide around buffer strips, I have found that most ag retailers can "map" the field to avoid spraying the perennial vegetation in the buffers, turning off individual spray nozzles as spray booms swing near or over them. This makes it easier than ever before to manage a field with buffer strips. Likewise, modern planters can be set up for precision planting around such strips.

Grazing cover crops

It is becoming widely recognized that one of the most profitable ways to use cover crops is to graze them. Most cover crop species are well-suited as forages and nearly all cover crop incentive programs now allow cover crops to be grazed, though some programs have certain restrictions on haying (cover crop haying may be allowed depending on date of haying and the specific incentive program). Alan Weber, an ag economist who grazes cover crops on a family farm with his father, did a detailed assessment of cover crop grazing economics and determined that a typical economic return would be a net profit of $49 per acre (2019 prices), assuming that the farmer already had access to portable electric fencing and water. Other groups, such as Practical Farmers of Iowa, have conducted case studies of individual farmers practicing cover crop grazing and found similar positive returns.

Common concerns about cover crop grazing involve hoof damage to crop fields and lack of fencing or water. Many farmers who graze cover crops are using single-strand electric fencing and portable water tanks, moving the cattle regularly between paddocks to maximize grazing benefit and reduce any potential hoof damage. In fact, I've heard a number of cover crop grazers say that they've been surprised by how the cover crop grazing system seems to make the ground more mellow over time (in this case, the mellower soil refers to being easier to plant into with better soil tilth). They also comment on

At top: Photo of a prairie strip planted on a contour in an Iowa soybean field (contour planting means planting perpendicular to the slope). These narrow strips of native grasses and flowering perennials provide habitat for pollinators, additional beneficial insects, songbirds, and other wildlife while dramatically reducing runoff of soil and nutrients. Photo courtesy of Iowa State University STRIPS program. At bottom: A mixed-grass border planted around the perimeter of an Indiana corn field. In this case, the grassed area would have been less productive due to adjacent tree roots, so the farmer felt the benefits for reducing erosion and controlling runoff were worth having a small reduction in production area. The farmer used cover crops in the corn portion of the field as an additional nutrient management solution.

the improved calf health when calves are born on green cover crop fields as opposed to dry lots.

Cover crop species used for grazing vary widely, but cereal grains such as cereal rye, winter wheat, triticale, and oats are the most common species grazed. A legume is often added to the cereals. Other farmers graze turnips (which typically winterkill) or rapeseed (which may overwinter in the southern half of the Corn Belt). Cover crop mixtures, either for summer and fall grazing after wheat harvest or as an overwintering mix, can be an effective way to meet grazing animals' nutritional needs while improving soil health.

Particularly beneficial to soil health are the manure, urine, and saliva from grazing animals, which stimulate the soil biology. Since soil microbes evolved with grazing animals, whether in prairie with buffalo or forests with deer and other herbivores, it's no surprise that recreating a more diversified system of crops and livestock should benefit soil biology. While more research on the full impacts of grazing livestock on soil health is needed, it appears that grazing cover crops is one of the fastest ways to boost soil health in many crop field situations.

For farmers who don't have their own livestock, it may be possible to rent out a cover-cropped field to a neighbor who will bring in

Beef cattle grazing cereal rye on a Missouri farm. Photo courtesy of Alan Weber.

portable electric fencing and portable water tanks. Creating a written agreement prior to the grazing is a good idea, including how the animals will be handled, when they will be removed, and any extra charges for delays in removing the livestock. The forage value of cover crops often exceeds that of perennial grass pasture, so rental rates should reflect the high value of the cover crop forage.

Diversifying crop rotations

While cover crops provide a key way to diversify a cropping system that normally has just one or two crops, it can also pay to add one or more additional cash crops to a rotation in order to reduce pest pressures, improve soil health, and diversify for varying weather and market conditions. Depending on the crop(s) selected, this diversification may also spread out labor demand, with different planting and/or harvesting periods.

A particularly common approach for corn and soybean farmers seeking to improve soil health is to add a small grain such as wheat or oats back into the rotation. Not only does such diversification provide modest yield gains for the corn and soybeans, it can also lower input costs. In some areas, addition of cereals may also improve cover cropping opportunities, because the earlier harvest date of the small grain allows more time to establish a cover crop. For example, if winter wheat is planted after soybean harvest, the following summer a diverse cover crop cocktail mix of 8-12 species can be seeded right after wheat harvest. These cover crop cocktails can produce a large amount of biomass and significantly improve the soil before planting corn the following spring. To outline how that three-year cycle could work (repeated starting in year four):

- Year one: plant corn, followed by a cereal rye cover crop in the fall
- Year two: plant soybeans into the rye, then plant winter wheat after harvest
- Year three: harvest the winter wheat, then plant a diverse cover crop cocktail in July
- Year four: back to corn, then use a cereal rye cover crop again after corn harvest

Sunflowers (top) and canola (bottom) are two oilseeds used to diversify rotations of other cash crops.

Ideally, the diverse cover crop cocktail planted after wheat harvest contains a mix of warm season plants and cool season plants. The warm season cover crops, such as sorghum-sudangrass, pearl millet, foxtail millet, sunflower, sunn hemp, cowpeas, and buckwheat, will predominate in the summer months and provide opportunity for late summer or early fall grazing. The cool season cover crops, if rainfall is adequate, will establish but stay small until fall, then take off in cool weather, continuing to grow past frost (some will overwinter); the warm season cover crops will die at the first fall frost. Cool season cover crops that can be blended into the cocktail include radishes and/or turnips, rapeseed, oats or a winter cereal, and one or more of the cool season legumes (crimson or red clover, hairy vetch, Austrian winter peas, etc.).

Diversification of crops makes a lot of agronomic sense and provides soil benefits, but marketing must be kept in mind. Distance to market can be a barrier to profitably using many alternative crops. It may be useful, instead of selling the crop to a distant contractor, to look at using the crop for livestock or other local uses (such as sunflower for birdseed sales). Local sales can also lower fuel costs by avoiding transporting harvested grain a long distance.

Another diversification option is to harvest selected cover crops for the seed market. However, be sure to research what grows well for seed production in your area. Some cover crops, like cereal rye, can be grown for seed in many regions. Others, such as some of the legumes and Brassicas, are better grown for seed production in the Pacific Northwest. If producing seed for your own use, be sure to clean the seed before storing and test for germination quality. If selling to other farmers, cleaning and germination testing is even more important. Be alert to any seed laws pertaining to seed sales in your state and be aware that selling seed across state lines is a more complicated process that can involve testing and certification (check with your state department of agriculture on state seed rules).

CHAPTER 11

What are potential issues with cover crops to be aware of?

Several years ago, when cover crops were just starting to become more popular, I gave a short talk on cover crops to a group of Missouri Extension staff. As soon as I finished, the questions started pouring in – what about problems with voles, slugs, cover crop weediness, etc.? There is an understandable concern from those who have only heard a little about cover crops that they may be a headache to manage. This chapter is an attempt to lay out some of the potential problems with cover crops, how likely they are to occur, and how you can deal with these problems. While it's somewhat unlikely that you personally will see one of these problems on your farm, it's good to be aware of the potential issues. The issues I will address are:

- Voles
- Slugs
- Insect pests and diseases
- Weed problems from cover crops
- Cover crop seed quality issues
- Termination and cash crop planting issues
- Crop insurance

Voles

Most cover crop users have never experienced a significant problem with voles, but for those who have, these small mammals can be quite a nuisance. Voles, as pictured below, appear similar to mice but are stockier, with smaller ears and shorter tales. They thrive on residue cover in certain regions of the country (see maps on page 178). Even without cover crops, they can show up in force in no-till fields. Cover crops don't necessarily increase the likelihood of voles compared to no-tilling without cover crops, but voles can reproduce rapidly wherever they have protective cover and a food source.

Distribution of meadow voles in map on left and prairie voles in map on right. Maps courtesy Cephas via Wikipedia.

In the U.S., there are several species of voles, but the two most likely to show up in crop fields are meadow voles (*Microtus pennsylvanicus*) and prairie voles (*Microtus ochrogaster*). The two species look similar and can be found on the same farm in the central U.S., but meadow voles tend to favor wetter areas and prairie voles tend to favor drier areas. As shown in the distribution map, meadow voles have a larger geographic range. Both types of voles like to eat a variety of vegetation, including clovers and vetches, but prairie voles are more likely to eat grasses than meadow voles. Both live in tunnel networks, but meadow voles tend to tunnel just under residue along the soil surface, while prairie voles may dig deeper tunnels.

Voles are short-lived animals, usually living for one to one and a half years, assuming predators don't catch them sooner. Their populations in a field can cycle up and down rapidly. They may be a major pest problem in a field for a year and then nearly disappear for a few years. Population peaks can occur in two- to five-year cycles. This is part of what makes control challenging, because after seeing them one year, the temptation is to treat the field with baits or other control methods the next year, when natural circumstances may have already caused the local population of voles to plummet.

There are a variety of control methods that can be employed with voles. None are foolproof but, used appropriately, they can lessen the chance of economic losses from voles. Voles eating some cover

At top: Meadow vole. Photo from U.S. Geological Survey. At bottom: Dead patches in a crop field caused by voles. Photo courtesy of Barry Fisher.

crop plants and residue isn't really a concern; the problem occurs when the vole population grows to the point where they start eating cash crop seeds or seedlings. Voles are somewhat more likely to be a problem in soybean fields versus corn or small grain fields. Sometimes, fields will be noticeably damaged with a patchy appearance, as shown in the aerial photo on the preceding page.

A long-term control method is to encourage the presence of predators, such as building raptor perches for hawks and owls at a few points around the edge of a field and allowing foxes or coyotes to frequent the area. If a large vole population is noticed in a no-till/cover crop field at the end of the winter, light tillage can be done in the affected areas prior to cash crop planting to destroy their tunnels and reduce cover, killing some of the voles in the process of tillage. Poison baits are available for voles, but should be a last resort, both because the baits can harm non-target animals and because they tend to degrade in rainfall, making them ineffective (some products may be slightly more water-resistant than others). Non-toxic baits such as excess corn or soybean seeds can be used as a distraction to direct smaller numbers of voles away from the planted crop.

The type of cover crop used may also have an impact on vole populations. It's been reported that voles particularly like vetch cover crops and that they also like clovers, whereas Brassica cover crops such as radishes, turnips, and rapeseed/canola seem to discourage vole populations. Where cover crop mixes are used, it may help to add a Brassica cover crop to the mix to reduce vole numbers, although more research on this is needed.

The amount of cover crop biomass may make a difference. Using a lower seeding rate of cover crops or including some winter-kill cover crops in the mix may reduce the stand of covers in the spring to the point where the voles have less shelter and are more easily killed by raptors; the lack of cover may also prompt voles to move to grassy field borders or other areas instead.

If converting a pasture or hay field to row crops, there is a higher risk for voles; scout for them in the months following conversion. Voles can also migrate out of grassy field borders into crop fields and are often worse around the edge of a field than in the center.

Scouting for voles is best done in early spring before cash crop planting, and signs may be easier to spot after a snowfall has melted. If five or more active burrows per acre are found, control measures may be warranted. As noted earlier, there are many areas of the country where voles are never or seldom seen, but they can occasionally be a problem in some fields every few years if management adjustments are not made. If you are looking for a silver lining, voles do eat weed seeds and can eat slugs and insect pests.

Slugs

Some of the same conditions that allow voles to prosper – namely high-residue cover either from no-till or cover crops – can also lead to slug problems. Slugs do better in moist than dry conditions. Various slug species are distributed widely in the U.S. and can affect many types of cash crops. They are seldom a threat to a mature field crop but can damage cash crop seeds and especially affect early seedling growth, either nipping off small seedlings entirely or chewing holes in the leaves of larger seedlings. If a cash crop can get past the initial seedling stage without significant slug damage, some leaf feeding during later crop growth will usually be inconsequential to harvested yields. The first few weeks of cash crop growth is the period when crops are most susceptible to slugs.

In the Midwest, the most common slug is the gray garden slug (*Deroceras reticulatum*), which typically emerges from eggs in mid-spring. An early-planted corn crop may manage to get a good jump on growth before these slugs emerge, and subsequently avoid any real damage. Severe slug damage can sometimes occur in late-emerging cash crops, most often during a cool, wet spring.

Slugs are less of a concern for the cover crop itself, although they have occasionally affected fall establishment of certain cover crops, especially when cover crop seed is broadcast (they eat the seeds lying on the soil surface). If slugs are a potential risk during the fall, drilling the cover crop seed can reduce or eliminate slug damage to the seeds.

At top: Close up of a slug. Photo by Nick Sloff, Pennsylvania State University. At bottom: Slug damage to young corn plants. A certain amount of damage can be tolerated if the crop is growing vigorously. Photo by Bobby Clark, Virginia State University Extension.

A key thing to know is that slugs are not insects; they are soft-bodied mollusks, similar to snails but without the shell. Thus, regular insecticides have no effect on them. However, there are molluscicides that can sometimes provide a degree of control. Iron phosphate baits are perhaps the most commonly used type of slug baits for field settings.

As with voles, a non-toxic control method is using tillage to terminate the cover crop and reduce cover available to the emerging slugs in mid-spring. This approach, however, is counterproductive to maintaining soil health and preventing erosion from heavy spring rains.

John Tooker at Pennsylvania State University is an entomologist who has spent a significant amount of time studying slugs in no-till and cover crop situations. He feels the best long-term approach is to encourage natural predators of the slugs, particularly ground beetles. To do that, broad-spectrum insecticide use must be curtailed in relevant fields. This includes obtaining cash crop seeds that are not treated with insecticide, which may necessitate a few phone calls to find insecticide-free seed from dealers or at least ordering the insecticide-free seed well in advance of the growing season. Insecticide-coated crop seeds have been found to greatly reduce the ability of ground beetles to control slugs, because they can cause impaired hunting ability or death. The slug slime can absorb the insecticide, with beetles that feed on the slugs accumulating toxic amounts of the insecticide, preventing them from preying on additional slugs. As stated earlier, insecticide-coated seeds and broadcast insecticides have no impact on slugs and don't provide any control of slugs.

Some other crop management tips for dealing with slugs:

- Close the seed slot so slugs can't access the cash crop seed
- Drill/plant deeper, again to keep the slugs away from the seed
- Diversify crop rotation because slugs may attack only one crop
- Plant corn earlier in the southern U.S. before slug emergence, or possibly later in the northern U.S. to encourage fast growth
- Use a pop-up fertilizer to boost early growth of corn or other nitrogen-responsive crops

Certain changes to cover crop management can also help reduce slug damage. When selecting cover crops to plant, avoid planting radishes and, to a lesser extent, other Brassicas, including in mixes; slugs seem to particularly like eating Brassicas. The amount of cover crop spring biomass can be reduced by cutting the cover crop seeding rate or mixing in more winter-kill cover crops. Planting green may help, as the slugs will keep eating the cover crop instead of the emerging cash crop; they will even eat the decaying leaves of a recently-terminated cover crop as the cash crop emerges.

Insect pests and diseases

Questions have arisen among plant pathologists, entomologists, and farmers about whether cover crops allowed to grow a long time in the spring will have a negative disease or insect impact on the following cash crops. A significant amount of research on this topic is underway and we are still learning about this topic, but I'll try to summarize what is known to date.

First of all, in most areas insect or disease issues are infrequent from using an overwintering cover crop before cash crops like cotton, corn, soybeans, sorghum, and sunflowers. If the cover crop is terminated early in the spring, pest and disease issues are particularly unlikely to occur. In some locations and in some years, there have been situations where certain insect pests such as armyworms have been worse following a cover crop. As with slugs, a planting green strategy might help because the armyworm will likely continue eating the much more voluminous cover crop biomass as opposed to the emerging cash crop seedling. There have been some exceptions to this in which the armyworms left the terminated cover crop and attacked the seedling cash crop. When armyworms are present in the cover crop, they should be periodically scouted and control remedies should be considered.

I want to emphasize that insect problems can potentially occur following cover crops, so field scouting is generally worthwhile. However, based on farmer experiences to date, overall insect pressure on cash crops following cover crops is not likely to be worse than conventional management on the majority of fields. With cover crops there can be specific insect pests that pop up in some places in some years but not others.

Another potential management issue is one that some scientists have described using the "green bridge" hypothesis, in which particular diseases or insects may move from the still-living green cover crop onto the emerging cash crop seedling. How much the green bridge issue happens with insects needs more study but is likely highly variable depending on the insect species and the year, based on factors noted above. With diseases, the green bridge problem is most likely if conditions are cold and wet; it's not yet clear how often this happens, but it seems to be a minority of cases, affecting corn more than soybeans. Observations to date suggest such disease incidence will be highly dependent on the weather that year and the timing of cover crop termination and death. If the cover crop is terminated, say, a week or so before the cash crop is planted, it's possible a certain insect pest or disease pathogen could move off the dead or dying cover crop leaves and start infesting the fresh, green cash crop seedling.

Overall, we have a lot more to learn about which insects and diseases might be worse following cover crops, when those problems are most likely, and how best to manage those situations. Some of the research currently underway at a number of locations in the U.S. should provide more guidance on this topic in the next few years.

Scouting fields shortly before and after planting cash crops is always a good idea. Scouting can be done in a time-efficient fashion and can allow a potential problem to be caught before there is a major economic impact. In southern or western areas where slugs are not a potential issue, a seed insecticide may help reduce any insect issues since there would be less concern about affecting ground beetle populations. In all areas, early termination of the cover crop is an option to reduce the chance of any disease or insect pests carrying over to the cash crops.

Weed problems from cover crops

One worry about cover crops I hear less than I used to is that planting cover crops will lead to a weed problem. The risk of a cover crop itself becoming a weed is very low. This is primarily because all of the 30-plus species of cover crops commonly available are domesticated annual plants that can be readily killed by a variety of herbicide, tillage, and other methods. The two biggest exceptions are hairy vetch and annual ryegrass.

The issue with hairy vetch is that a significant portion of the seed normally has a hard seed coat, and these hard seeds don't germinate right away. Some may germinate a year or two after planting, and others may not germinate until several years after planting, when weathering conditions have broken down the hard seed layer. Efforts are underway to breed new varieties of hairy vetch that don't have hard seed, so that may be a solution in the future.

Another issue with hairy vetch is not directly a weed issue but relates to the size of the hairy vetch seed. Hairy vetch seed is of a similar size to wheat seed, so any hairy vetch that happens to grow (volunteer) with the wheat will not be separated during combining and will end up in the truckload of wheat going to the market. This can lead to a financial penalty (docking) when the wheat seed is delivered or, if bad enough, may cause a truckload of wheat to be rejected, with the only alternative being to feed it to livestock. Thus, it's a good idea to avoid planting hairy vetch in fields where wheat will be planted for harvest in the coming years.

Annual ryegrass has a different issue. It's more challenging to terminate than other cover crops and carries the risk of developing into a glyphosate-resistant weed population in a field. This is unfortunate, because annual ryegrass (a completely different species and genus of plant than cereal rye), has many excellent cover crop attributes such as easy establishment, deep rooting, erosion protection, and good forage quality. I generally suggest farmers avoid annual ryegrass unless they're willing to pay particular attention to their termination strategy. Effective chemical termination of annual ryegrass involves spraying early in the afternoon on a sunny day when air temperature is above 55°F and soil temperature is above 45°F, and while the ryegrass is actively growing. A good guide with details on how to manage annual ryegrass as a cover crop, including termination strategy, is *Annual Ryegrass as a Cover Crop in Midwest Corn and Soybean*

Production. That publication is available for free online and can be found by searching for that title in an internet search engine.

The real issue with weeds related to cover crops is not the cover crops themselves, but weed seed that may be in the cover crop seed supply. Reputable seed dealers of cover crops do a thorough job of cleaning their cover crop seed, just as is done with cash crop seed. However, some farmer-to-farmer sales of cover crops have contained excessive amounts of weed seed due to inadequate cleaning of the seed; this is particularly problematic if noxious or herbicide-resistant weeds are found in the cover crop seed purchased. It's always a good idea to review the seed tag on the cover crop seed to verify that it has been cleaned to a high standard; if no seed tag is available, that's a warning sign that the seed should not be purchased.

Cover crop seed quality issues

Much like the previous discussion on weed seed in cover crop seed supply, it's important to review a seed tag for germination percentage. Generally, a germination percentage of 85% or greater should be expected for the cover crop seed, and foreign material should be minimal. There have been cases in which a farmer ended up with a truckload of poor-quality seed that did not germinate well, perhaps because they went with the cheapest source of seed or were ordering late, when good-quality seed had all been sold and only low-quality bin-run seed was left.

Another issue to be aware of related to seed purchase is Variety Not Stated (VNS) cover crop seed versus buying a named variety. It's an unfortunate reality that much of the cover crop seed currently sold in the U.S. is sold as VNS. The problem here is that a Minnesota farmer might end up with a type of cereal rye best adapted to the south, and a Florida farmer might end up with rye that's better for the north. Often, VNS seed is a mixture of varieties, which can lead to inconsistencies in cover crop performance and development, potentially complicating termination timing. My hope, similar to many seed industry leaders, is that we soon see a shift away from VNS cover crop seed. We need to transition to using only named varieties of cover crops that are adapted to the region, just like is done with cash crop seed.

Termination and cash crop planting issues

Detailed management suggestions for cover crop termination and how to plant a cash crop into cover crops were addressed in Chapters 6 and 8. The following section is just a short review of some particular issues to avoid.

The two main issues regarding termination are the timing and completeness of the termination process. With timing, the biggest factor is the amount of soil moisture at the time of termination. In the case of spring-terminated cover crops, a wet spring is a reason to let the cover crop grow longer and continue drawing down the soil moisture in advance of cash crop planting. However, there have been cases in which farmers terminated cereal rye that was 2 to 3 feet tall about 10 to 14 days ahead of desired corn/soybean planting, and then the weather turned rainy and the cover crop created a wet mat that further delayed cash crop planting. By leaving the cover crop alive until planting time, that situation can be avoided. Just keep in mind that if the spring is trending dry, that's a good situation in which to terminate early, such as when the cover crop is still less than a foot tall.

Completeness of termination refers to achieving 100% kill on the cover crop so that none of the cover crop plants bounce back and interfere with cash crop growth. Most of the common cover crops are easily controlled by herbicides if the proper spray rate and products are used. Potential problem situations include spraying when it's too cold, and the cover crop doesn't actively translocate the herbicide or having a thick mat of cover crop that's been knocked down by rain and wind, so that it's difficult to achieve direct contact with all the cover crop plants when spraying.

If mechanical control methods such as roller crimper or mowing are used, it's best to wait until the cover crop has turned reproductive (started flowering) and then roll or mow. If rolled or mowed while still vegetative, the cover crop may bounce back and continue to grow. If using a mower, cut the cover crop as close to the ground as is feasible. Termination by tillage can be done at any time of cover crop growth, vegetative or reproductive; dislodging the cover crop roots is usually the key to complete control. By contrast, merely slicing up some cover crop top growth with a disk may inadvertently allow cover crop regrowth unless repeated tillage passes are made.

When planting a cash crop into the cover crop, there are two general approaches to pursue. For a first-time cover crop user, especially someone who has just one or two fields of cover crops, it's usually best to terminate early so that there is little cover crop biomass and planter modifications are minimal. However, for full value of the cover crop, as experience is gained with cover crops, you should plan to experiment with later termination and adjusting planter settings. Getting good furrow closure should be a high priority, and that may require changing out closing wheels. In finer-textured soils, it may be helpful to have one or both of the closing wheels on each planting unit be a spiked-type wheel that can help break down the firm sidewalls of the seed furrow. More traditional round closing wheels, whether rubber or steel, may not provide full furrow closure in a no-till cover crop system.

Having sharp furrow openers can be helpful in some cases to slide through residue and open the furrow. However, trash-clearers on planters are often unnecessary with cover crops and may in fact get tangled with cover crop biomass. I've heard quite a few farmers say they ended up taking trash-clearers off their planter because of the tangling issue (cotton farmers may be more likely to use row-cleaners given the shallow planting needs with cotton). No-till coulters may or may not be helpful in cover crop situations. A reason not to use no-till coulters is that it's best to have maximum down-pressure from the planter weight on the furrow openers, and if a coulter is present, part of the planter weight is going onto the coulter instead. Again, experimentation is the key. Taking some time at the beginning of planting a cover cropped field to adjust cash crop planter settings can really pay off in achieving a good stand of the cash crop.

Crop insurance

I've been in dozens of meetings and conference calls on crop insurance related to cover crops, mainly because crop insurance was an early barrier to some farmers using cover crops. Many of those meetings over time have contributed to significant improvements in crop insurance policies for cover crop users. There are still misperceptions out there that planting cover crops will somehow mess up crop insurance eligibility. Fortunately, current federal crop insurance policies are much more conducive to using cover crops and cover crops only rarely impact eligibility for cash crop insurance.

Here's where things stand at the time of writing: there are no restrictions on planting cover crops after cash crop harvest or overseeding cover crops shortly before cash crop harvest. Fall cover crop planting has no impact on crop insurance eligibility for the next cash crop. However, termination of the cover crop should be done according to what insurance people call "Good Farming Practices (GFP)." The GFP guidance applies to many agronomic practices beyond just cover crops. For example, you can't mistakenly spray a grass herbicide on wheat or corn, injuring the crop, and expect to collect a crop insurance payment. In that situation, GFPs weren't observed. Likewise, a farmer can't skip cover crop termination, letting the cover crop grow so long that it prevents good establishment of the cash crop and still expect to file for a full crop insurance payment.

After considerable debate on how to handle cover crop termination in relation to crop insurance, we currently have a system where farmers can refer to local experts, regional cover crop council guidance, or cover crop termination guidelines posted on the NRCS website. You don't have to follow the recommendations of any one particular group, but you do need to have one of these kinds of reference points. Use of such local/regional expertise provides a defense in case a crop insurance payment is questioned regarding whether GFPs were followed. Letters from local cover crop experts, such as Extension agronomists, can also be used to help clarify whether regionally appropriate practices were used for termination.

The other potential insurance issue with cover crops and crop insurance is interseeding a cover crop early in the growing season of the cash crop. Some farmers have experimented with planting a cover crop at the same time they plant the cash crop. Others have interseeded partway through the growing season, such as using a high-clearance grain drill to seed a cover crop into knee-high corn. Still others have tried planting cover crops early into extra-wide corn row spacings, such as 60-inch corn rows. Because these are non-standard practices, it's possible that a crop insurance payment request might be questioned. As with termination, getting letters from local cover crop experts or finding regionally published guidelines on the validity of the method can help resolve any such crop insurance disputes.

A special circumstance that became a major issue in 2019 was the 19 million acres of cash crops that were declared "prevented planting," meaning that they could not be planted to crops such as corn and soybeans within the accepted time window for reasonable yields. At first, there was substantial confusion about whether farmers could immediately go in and plant a cover crop, especially if they intended to harvest that cover crop for hay. Since then, the Risk Management Agency (RMA) has put out clarifications that a cover crop can be planted at any time after prevented planting is declared without payment implications, provided the cover crop is not harvested for seed. Specifically, on July 6, 2021, RMA published on their website the following language: "A cover crop planted on acreage claimed as prevented from being planted can be hayed, grazed, or cut for silage, haylage, or baleage at any time without a reduction to the prevented planting payment, provided the insured meets all other policy provisions. However, a cover crop harvested for grain or seed at any time will result in a prevented planting payment reduction in accordance with section 15(f)(2) of the CCIP Basic Provisions."

The bottom line is that a farmer using commonly accepted cover crop management for their region has no reason to fear losing crop insurance. You do need to be aware of particular restrictions on harvesting the cover crop for seed and then planting a cash crop – that will typically mean any crop insurance payout for the cash crop will be evaluated at a lower "double crop" yield rate since the cover crop seed harvest is viewed as the first crop in the cropping year. Growing a cover crop for hay harvest prior to cash crop planting can also potentially impact cash crop insurance payout amounts, depending on the time of haying and particulars of the situation (policies on haying continue to evolve, so check for the latest).

Federal policies on crop insurance are regularly revised. While the crop insurance information in this section reflects policies as of early 2023, it may be worth checking on the latest policies posted on RMA's website if you have any question about crop insurance eligibility in relation to cover crops. This is particularly true if you are trying some uncommon practices with cover crop management.

CHAPTER 12

Grazing cover crops

There are many good reasons to consider grazing crops. It's one of the fastest ways to not only build soil health but also to make cover crop use profitable. Increasingly, many farmers are finding benefits from grazing cover crops, with the financial benefits being at the forefront. Grazing cover crops can reduce the need for expensive hay and improve the rate of livestock weight gain at times of the year when perennial pastures are less productive. Cool season cover crops can be helpful for grazing in late fall and spring, while warm season cover crops provide summer and early fall grazing options. Many cover crops can provide excellent-quality forage for a multi-week period, and using a variety of cover crops can extend the period of time when grazing is available. The high-quality forage can be particularly helpful for lactating cows, which need higher levels of nutrition. Integrating livestock into crop fields through cover crop grazing makes sense when considering that soil microbial communities

Cattle grazing cover crops in early April in Missouri.

evolved with grazing animals, such as buffalo on the prairie. The soil microfauna responds positively to the manure, urine, and saliva from grazing animals, leading to better soil health over time. When the grazing is done with management-intensive rotations, it helps spread the animal impact across the crop field more evenly, and maximizes both soil benefits and efficiency of forage utilization.

Grazing of cover crops works well with single species and many grazers also use cover crops mixes, adding to the biodiversity of the overall cropping system. Such plant diversity has been shown to boost diversity of soil microbes, adding to soil health. Depending on the species being grazed and the timing of grazing, habitat and food for beneficial insects and wildlife may also be improved. Another positive is that slug and vole issues may be reduced by the removal of some of the biomass that would otherwise provide favorable conditions for those pests.

Some cattle producers have noted that grazing cover crops seems to add to animal health, especially by providing an extended period of grazing when otherwise animals would be in a bare lot feeding on hay. Calves born out in a cover cropped field have been found to stay healthier and need fewer visits from vets, in part from less exposure to wet muddy conditions that might occur in a confined lot.

Cover crop grazing economics

Potential profit from cover crop grazing will vary but in most cases is net positive if water and fencing are already available. However, starting from scratch by purchasing new fencing and creating a water supply can delay a positive net return for a year or two, depending on upfront costs. Virtual fencing, described more below, is one way to lower your initial fencing costs, but standard electric fencing can also be used with a modest investment. Water costs can be highly variable, but on the low end you can use a towable water trailer or pump from a nearby surface water source through a temporary line as cost effective starting points.

Total returns from cover crop grazing will depend on the number of days the forage can be grazed, the quality of the forage, and the efficiency with which the forage is being utilized. Using management-intensive grazing techniques will reduce trampling of the cover crop and allow livestock to use the available plants more efficiently for weight gain. When hay costs are high and pasture grass is insufficient, cover crop forage becomes even more valuable, making it part of a good overall strategy for livestock grazing.

Hurdles with cover crop grazing

Despite the obvious benefits of cover crop grazing, there are hurdles to get over when adding this practice. These include matching animals to the cover crop opportunity from a location and timing standpoint, implementing a fencing strategy, and determining a watering method. These are addressed in more detail below. Some crop farmers also have concerns about potential compaction from cattle specifically, more so than with smaller stock like sheep and goats. While cattle can cause localized compaction if allowed to stay for too long in a given area, this issue can be reduced by management intensive grazing. Moving the water supply and keeping cattle off overly saturated soils can also help reduce the potential for compaction. When using appropriate rotational grazing strategies, most cover crop grazers find they are able to avoid any significant compaction issues, and in fact many find that their overall soil tilth improves from the grazing process.

Matching grazing animals to available cover crop forage

For producers who either lack their own livestock or only have seasonal stockers, some planning is required to have animals available at a time that matches up with cover crop availability. Some producers who manage stockers have found that instead of just adding weight to young animals and shipping them off elsewhere for finishing, they can use the high forage quality of the cover crops to finish the animals before going to market. Of course, that opportunity will depend on access to slaughtering facilities, the type of livestock, and overall management goals.

For those producers who don't own grazing livestock, they may be able to work with a neighbor who does have animals they can graze.

Leasing a cover crop field can be an extra way to gain income on the cover crop and offset the cost of seed. Using a fair and well-structured grazing lease is important. The lease should include the number of days animals will be allowed to graze and identify the dates when field access will start and end, likely with a per-day financial penalty for keeping animals on a field past the target removal date. Grazing payments are occasionally based on the amount of weight gain, but weighing livestock in and out can create extra work. A more common approach is a lease payment based on the number of grazing days and/or based on stocking density. Leases should also address how fencing and water will be provided, and who is responsible for maintenance and any repair costs. Leasing rates for cover crop grazing often exceed those for pasture grazing, due to the higher quality of the cover crop forage at key times of the year, but that can be very location specific and may vary seasonally.

Fencing strategies, including virtual fencing

If a cover cropped field already has perimeter fencing, that's a real plus, but the reality is few crop fields have permanent fencing around them. Most cover crop grazers rely on temporary electric fencing for field boundaries, perhaps putting two to three strands of hot-wire around the perimeter of a field and then subdividing the field using single-strand electric fencing with step-in posts to create grazing paddocks. Solar chargers can power the electric fence and are readily available at many farm supply stores. Online videos can be found showing how producers have figured out efficient methods of quickly setting up and taking down electric fencing, in some cases using ATVs or UTVs to quickly manage the fencing.

While electric fencing can be cost-effective for cover crop grazing, there's no question that virtual fencing now offers some labor savings for managing grazing animals when moving them frequently. Virtual fencing not only saves labor, but allows more real-time monitoring of animals, providing alerts if grazing animals have stopped moving or have escaped designated grazing areas. Several companies now have virtual fencing products on the market.

All virtual fencing systems use a collar around the neck of the grazing animal. Attached to the collar will be a case of some type with a battery and typically a small solar panel or panels; some systems have a case hanging from the neck like a cow bell and others have the case with battery and solar panels on top of the neck. Batteries are designed to hold a charge even during long periods of cloudy days. The battery in each collar will power a sound cue (like a beeping sound) that the grazing animal hears when they approach the grazing boundary that you have established virtually. If they go too close to the boundary they will get an electric shock, but nearly all animals quickly learn to just turn around when they hear the sound, and thus avoid getting shocked.

Virtual fencing collars have a GPS receiver for picking up satellite signals to detect where the animal is located and help keep it within the designated grazing area. The collars will also have either a way to communicate directly over a local cell phone network or with an on-farm tower that relays the signal to a cell network. Grazing paddocks can be quickly outlined on a phone, tablet or computer, which also serves to provide monitoring information on the animals. The designated grazing boundaries can be irregular, to better follow stream or woodland borders and keep animals out of sensitive areas while allowing you to design appropriately sized grazing wedges, strips, or other paddock shapes.

Costs for virtual fencing systems are still evolving, so check with a few of the virtual fencing companies to get current pricing. Some provide collars at no charge but make their money from monthly subscription fees per collar, whereas other companies have a fee for the collar and a separate subscription fee. Fortunately, in many states the USDA Natural Resources Conservation Service (NRCS) is starting to offer incentive payments for farmers to adopt virtual fencing, making it more affordable to try integrating this new technology that can make cover crop grazing easier.

A key caution for virtual fencing systems is that a physical fence is still strongly recommended around the perimeter of any field adjacent to roadways. This provides additional safety for both the livestock and passing motorists. That physical fence can be either a permanent fence or a less expensive, temporary electric fence.

Cattle with virtual fencing collars. The style and configuration of collars varies between companies, but most have a solar panel recharging a battery powered system.

Water

A limitation of many crop fields for cover crop grazing is a lack of onsite water. Some fields may be next to a pond or stream. Although grazing animals are often allowed direct access to such surface-water sources, it is helpful for water quality reasons to keep livestock out of streams or at least limit their access. An alternative is to use an efficient gas-powered water pump to move water to a nearby moveable tank that the animals can access.

Unlike with a permanent pasture, digging a well in a crop field or running buried water lines is not likely to be cost efficient unless the water is needed for other purposes, such as irrigation. If no wells or surface water sources are near a field, towing water tank trailers to the field and filling a livestock watering tank may be the most practical solution, especially for smaller herds of grazing animals.

Anyone considering cover crop grazing should plan ahead for a watering strategy, including how to move watering devices periodically so that grazing animals don't overly compact a particular watering site. Financial assistance for certain types of watering systems may be available from NRCS.

Timing of grazing and maximizing cover crop forage

The SARE/CTIC National Crop Survey has included questions about cover crop grazing. For the producers responding to the survey, about a third each grazed only in fall, only in spring, or in both fall and spring. As producers get experience with cover crop grazing, some add summer cover crops after a small grain harvest, allowing additional opportunities to benefit from grazing.

For fall grazing, it's important to allow the cover crop to get established as early as possible, allowing adequate plant growth before starting grazing. This is particularly key for overwintering cover crops so that the plants get established well enough to survive both the grazing period and winter conditions. Many producers planning to fall graze will either switch to earlier maturing corn and soybean varieties, which allows for earlier post-harvest cover crop planting, or will overseed the cover crop into the corn, beans, or other summer crop prior to harvest. For many years, aerial application with planes and helicopters has been used with cover crops to allow interseeding. More recently, drones have started to be used for flying on seed. Alternatively, some farmers and companies have used high-boy spray applicators adapted to interseed cover crops. Broadcasting cover crops into a standing commodity crop can allow for earlier cover crop establishment if timely rain occurs, but is a riskier strategy than drilling the cover crop after planting.

Fall grazing for most covers should wait until the cover has several inches of growth, but the exact height will vary depending on cover crop species and growing conditions. Also, if the cover crop is expected to regrow in spring, carefully managing the fall grazing so that the cover crop is not overly stressed (grazed too hard) will matter for its winter survival. A rough rule of thumb is to leave at least half the aboveground biomass of fall-planted covers, but again this varies. On the other hand, if the cover crop is one that will winter kill in your region, such as oats or turnips, the biomass utilization can be more extensive since recovery of the cover crop is not expected.

For spring grazing, waiting until the cover crop actively starts growing is necessary. Clear signs of green up and spring growth should be seen. On the other hand, it's also important not to wait too late to graze. For example, once cereal rye starts heading out, cattle will start to lose interest in grazing it. Length of spring grazing varies by plant species, so if extended spring grazing is desired, choose a late maturing variety of an appropriate species, such as wheat.

Additional opportunities for cover crop grazing can be created by making space for summer cover crops in the overall crop rotation. Summer cover crop mixes that include species such as sorghum-sudan, millets, sunn hemp and cowpeas, can provide excellent forage with a large amount of biomass. Such summer cover crop mixes do well when planted with a drill soon after small grain harvest. These mixes can be grazed in late summer or early fall, and possibly again in late fall if not overgrazed on the first pass. Adding some cool season cover crops to the summer mix can increase the ability to do a late fall grazing and may make it possible to get yet another grazing pass in spring.

For farmers in the Corn Belt who want to maximize cropping system diversity and build in plenty of grazing opportunities, one approach is a three-year corn-soybean-wheat rotation that includes six possible windows for grazing in the following eight-step sequence:

1. Plant winter wheat for grain, and do a light grazing that fall; however, don't spring graze to avoid impacting wheat grain yield unless forage is of prime importance.
2. After harvesting the winter wheat, drill a diverse mix of warm season annuals, including two to three species each of grasses, legumes, and other broadleaves, plus a few cool-season cover crops like oats, radishes, clovers, etc.
3. Graze that summer cover crop mix in late summer or early fall.
4. After regrowth of the cover crops, graze again in late fall (after a frost, wait at least five days before grazing to avoid temporary spikes in cover crop nitrates and also prussic acid in sorghum-related species).
5. If possible, graze the cover crops again in spring before planting corn (corn seems to do particularly well after such diverse

summer cover crop mixes).

6. Right after corn harvest, drill in cereal rye at a relatively high seeding rate to boost the biomass, then fall graze if adequate rye growth occurs. Some oats can be added to the rye to increase fall biomass.
7. In spring, graze the rye again, then plant soybeans.
8. After the soybeans, go back to winter wheat.

Wide-row corn

Another way to get a lot of biomass for cover crop grazing is to plant wide row corn. Some farmers have experimented with corn on rows as wide as 60 inches to allow more light for a cover crop mix that is seeded either at the same time as the corn or interseeded into young corn in early summer. In the modest number of trials that have been reported on this type of corn interseeding (sometimes referred to as the "solar corridor" approach), corn yields are reduced but can still be relatively good while producing large amounts of cover crop biomass. The corn is harvested for grain by running the corn header above the height of the cover crop plants (so selecting shorter cover crop species may be needed), then the cover crops are grazed. Some farmers will alternatively graze the whole field before the corn reaches maturity, since the corn can also provide some good forage value with the cover crops.

Cover crop species for grazing

Chapter 7 provided an introduction to most of the cover crop species being sold in the U.S. Nearly all of those cover crop species have some potential for grazing, but of course some species are better suited than others for this purpose. Below is a summary of many of the more common cover crops used for grazing, with comments about the particular value of each species for grazing use. Be sure to also read the section on potential cover crop toxicity issues near the end of this chapter.

For those interested in native plants for grazing, there are a number of perennial plants in the forage trade that are used for grazing, especially native tallgrass species like big and little bluestem, Indiangrass, gamma grass, switchgrass, and some native shortgrass species used in the western U.S. Unfortunately, there are relatively few readily available options for annual cover crops that are natives, due to lack of seed development. Native annual species exist that probably could work well for grazing, but commercial seed is either very expensive or not even available. This is an area for future research and development efforts, making more use of native plants as annual cover crops. Most of the species outlined below are not natives but are annuals that have fast growth suited for use as temporary cover crops in rotations with annual cash crops. Chapter 14, on horticulture systems, details some perennial covers that can be grown in orchards, vineyards, and other settings where seasonal grazing may also be a possibility.

Cool season grass cover crops

Cereal rye. Rye is not only the most common cover crop overall, it is also one of the most common for grazing. It is reliable for over-wintering in tough conditions and can be planted later in the fall than any other cover crop. However, for fall grazing use, rye should be planted as early in the fall as feasible, otherwise grazing may need to wait until spring when more biomass is available from the rye. Early to mid-spring grazing can be excellent but rye develops high lignin as the spring goes on and palatability to grazing animals will decline faster than in wheat, triticale, or barley. Rye for grazing is normally planted at a high seeding rate if used as the sole species; in mixes intended for grazing, back off on the rye seeding rate to allow space for other species such as legumes to be able to compete.

Triticale. As a cross between wheat and rye, triticale is intermediate in performance between the two, being fairly hardy but slower growing than rye in the spring. It is sometimes favored over rye because it can be grazed for longer in the spring and it stays shorter than cereal rye.

Wheat. Winter wheat works well for both fall and spring grazing, having a longer period of forage utilization in the spring than rye. It does need to be planted earlier than rye in the fall to ensure winter survival and may not do as well in more northern areas.

Barley. Some grazers in the southern half of the Corn Belt like winter or spring barley for grazing. It has lower lignin content and is highly palatable to livestock, but once it heads out, the seed heads can become irritating to grazing animals.

Oats. Winter oats will only overwinter in the most southern parts of the Corn Belt, but despite the lack of winter hardiness in oats, it is often planted for fall grazing either alone or in mixes due to the rapid growth it achieves in the fall. Planted on the same day as winter cereals, it will get greater height and more fall biomass than the winter cereals, which are putting more energy into their root systems to help them survive the winter. There can be some differences in performance between spring oats, winter oats, and black-seeded oats, with the latter two growing a bit longer into early winter than spring oats.

Annual ryegrass. Perhaps the easiest of the cool season grass cover crops to broadcast establish, ryegrass is highly palatable and stockpiles well (meaning it can still be effectively grazed even after active fall growth has ceased). Ryegrass often overwinters in the southern Corn Belt but doesn't reliably overwinter in the northern Corn Belt. Despite the similar names, annual ryegrass is a completely different genus and species of plant than cereal rye. A caution with annual ryegrass is that it can be more challenging to spring terminate than other grass cover crops, and weed specialists typically discourage its use because of potential weediness.

Warm season grasses

Sorghum-sudan. The sorghum family of plants offers several options for summer cover crop use, with sorghum-sudan perhaps being most common. It grows rapidly, is drought-tolerant like other sorghums, and produces a large amount of forage biomass. While it and the other sorghums can be planted as a sole summer cover crop for grazing, they are more often mixed with other cover crop species.

Sudangrass. Compared to sorghum-sudan, sudangrass is finer-stemmed and somewhat shorter with less biomass, but also offers a lower risk of prussic acid poisoning (more on this in the toxicity section below). It is suitable for making hay as well as grazing.

Forage sorghum. A taller type (8–12 feet) of sorghum than regular grain sorghum, forage sorghums have many of the same attributes as the two species above but with wider leaves and thicker stems along with the highest potential for biomass. Forage sorghums can be grazed while still vegetative or after a seed head has been produced, adding some extra protein from the seed. A downside of forage sorghums and grain sorghums is the higher risk of prussic acid poisoning from them.

Forage pearl millet. As with sorghum, there are both shorter grain-type pearl millet varieties and taller forage-type varieties. The latter are popular in summer cover crop mixes, with excellent drought tolerance and relatively rapid growth. Pearl millet can be a bit harder to broadcast establish than some other grasses, so drilling at an appropriate depth is recommended. Pearl millet does not cause prussic acid poisoning (nor do other millets), so that is another factor in the popularity of this species for cover crop grazing. However, it does not produce quite as much biomass as the better forage sorghum varieties.

Foxtail millet. A popular summer cover crop, especially favored for its fast growth and easy management by horticultural producers, foxtail millet also works well for hay and grazing use. While not nearly as tall as the grasses listed above (it typically gets 3–4 feet tall), it does grow quickly and works well as part of mixes, with high palatability to grazing animals. The fact it produces a seed head quickly allows it to add some protein through seed production in grazing mixes. It's also a good one to support songbirds and game birds in grazing mixes (most of the grasses listed here are also beneficial for birds if they produce seed).

Other millets. Several other millets exist, as noted in Chapter 7, representing a range of disparate species from different parts of the world. Most can be used in grazing mixes. Japanese millet and browntop millet are good options for fields that may have wetter soils, though they can also grow fine in drier conditions. Using a few different millets is a nice way to add some biodiversity among the grass family members of a cover crop mix.

Teff. Sometimes lumped in with the millets, teff is a short-statured (1.5–2.5 feet), fine-textured grass that is very drought tolerant. It matures quickly and is most popular in the western hay market, though it certainly can be grazed. Its downside in a summer cover crop mix is lack of competitiveness with taller grasses, but it could still have a role as an understory plant in a diverse mix.

Cool season Brassicas

There are no warm season Brassicas, so anyone seeking to add cover crops from the Brassica (mustard) plant family to a grazing mix is limited to cool season options. The available options will all do best if planted in late summer or early fall. If planted in mid- to late fall, they will generally get little growth, and relatively few of the Brassicas overwinter, so their best grazing use is in the fall, assuming adequate time exists for fall growth. Most often, when used as a single species, they are planted after small grain harvest since that allows more time for the Brassica to get good fall growth. As part of a diverse cover crop mix, it can be reasonable to include Brassicas at a low seeding rate, recognizing their greatest value will occur with earlier fall planting dates. Fortunately, Brassicas can be broadcast established into standing crops, just be alert to the fact that Brassicas are more sensitive to certain residual herbicides than most other cover crops.

Turnips. For fall grazing, turnips are the most popular Brassica option for cattle producers, either alone or preferably as part of a mix. Cattle will graze the leafy greens first and later will eat the tops of the turnip tubers, providing a good food source into early winter.

Radishes. While the tuber of radishes is not as accessible to grazing animals as turnips, the leafy top growth is equally valuable to grazers. For that reason, it's not uncommon to see both turnips and radishes in a diverse cover crop mix for grazing. There are a variety of radish varieties with different characteristics on the market, so consider overall cover crop goals in selecting a variety.

Canola/rapeseed. Both turnips and radishes will normally winter kill outside of southern states, leaving winter canola or winter rapeseed varieties (both are the same species of plant) as the only overwintering option among the Brassicas. Canola/rapeseed lacks the large tuber of radishes and turnips but have equally impressive fall leaf growth (if planted early) and can provide good grazing, especially mixed with a grass and possibly with a legume. Be aware that when planted in early fall, canola or any of the Brassicas can be quite competitive and may shade out legumes in particular and even some of the grass cover crops. To avoid this issue, plant a very low seeding rate, typically at most 1 pound per acre and often much less in a highly diverse mix.

Winter camelina. The most winter-hardy of the Brassicas, winter camelina can survive even winters in North Dakota. It can also survive later plantings than canola and certainly is usable much further north than canola/rapeseed. However, whereas the other Brassicas listed here have the ability to produce sizable fall rosettes of leaves, camelina has a much smaller fall rosette and doesn't contribute much to fall grazing. It is a more viable option for spring grazing, assuming it is allowed to get some spring growth before the grazing starts.

Ethiopian mustard and other mustards. While not as commonly used as the Brassicas above, Ethiopian mustard (also called African cabbage) can put on a large amount of fall growth. It's probably the most vigorous among the mustards for fall leaf growth if planted in early fall. However, like radishes, it won't overwinter except in very mild winter locations. A number of other mustards exist, such as kale, collards, and yellow mustard, and may have a place in certain mixes.

Cool season legume cover crops

Crimson clover. Several clover species made their way from Europe to the U.S. over the years for use in grazing and hay production systems, with a few gaining popularity as cover crops. Crimson clover is the most popular legume cover crop in the U.S. but is limited to the southern half of the Corn Belt due to only modest winter hardiness. Its popularity derives in large part from its fast growth, making it able to produce a valuable amount of high-quality forage. While crimson clover could be grown by itself for grazing, due to potential issues with bloat in livestock it's best to mix it with grasses, such as oats and/or a winter cereal. Bloat is a problem that can occur when livestock first start grazing lush growth of pure legume stands. It is worse with some legumes than others; for example crimson is considered to be less of a risk for bloat than alfalfa, red, or white clover.

Balansa clover. A newer clover option in the marketplace, balansa clover has value as a type of clover with a lower risk of bloat (not completely risk free, however). It can put on an impressive amount of late spring growth. Balansa clover is similar in growth habit to crimson clover (both are winter annuals), but may be winter hardy a little further north than crimson. It's also reported to be more tolerant of wet soils in winter than crimson clover. Balansa clover produces significantly less biomass than crimson clover in the fall and early spring but comes on strong in late spring, growing 3 feet or more high. Mixing crimson and balansa together with one or more grass species can be a decent option for fall and spring grazing.

Red clover. A clover adaptable to more northern areas is red clover. Considered a short-lived perennial as compared to a true annual, it grows slower than crimson clover but can be a fit where an overwintering legume is sought in more northern areas. Early to mid-fall establishment is needed to achieve reasonable winter survival. Red clover can cause bloat, so again it's best to mix it with non-legume species like grasses.

White clover. As is evident by its ability to bounce back from frequent mowing in residential lawns, white clover is quite tolerant of heavy grazing. However, compared to other clovers it produces considerably less biomass. It does have the ability to tolerate light shade.

Berseem clover. Berseem is a viable over wintering option for southern cover crop areas and can be used for fall or spring grazing further north, but it normally won't overwinter outside the south. Its quality as a forage is quite high, sometimes being equated to alfalfa.

Warm season legumes

Cowpeas. Commonly used in cover crop mixes, cowpeas are planted in the warmer months of the year. The iron clay type is a vining plant that can integrate well in a diverse plant canopy and is readily available in the market. As with other legumes, be sure to get the right type of seed inoculum to ensure nitrogen fixation takes place. They can rebound from some light grazing but as with the other warm season legumes listed here, the first light frost will kill them.

Mung beans. Coming from the same genus of plants as cowpeas, mung beans have a lot of similarities to cowpeas but are a different species. They are drought tolerant and grow fast, though usually produce less biomass than cowpeas. If just picking between cowpeas and mung beans, cowpeas would often be the better choice given similar seed prices. However, to diversify a summer cover crop mix, mung beans can be a decent addition.

Sunn hemp. As a legume from more tropical areas sunn hemp won't produce seed in most areas of the continental U.S., but does grow quickly in the summer, reaching 6–8 feet tall in two months or less. Like cowpeas and mung beans, it can tolerate dry weather, and both are strong nitrogen fixers. It can regrow after light grazing, but heavy grazing will normally suppress much further growth.

Soybeans. In a corn and soybean rotation, adding soybeans to a cover crop grazing mix is far from ideal, but for other cropping systems it may be an option. Forage-type soybeans still exist that can get as tall as 6 feet. Although domesticated in China as an oilseed crop, soybeans were first used in the U.S. for decades as a forage before farmers began to routinely harvest them for seed.

Other summer broadleaves

Sunflowers. While the rough leaves and stalks are not quite as palatable to grazing animals as the species listed above, they do get eaten in mixes, and most grazing animals do like the seed heads due to the fatty seeds once the sunflowers reach that stage. Very drought tolerant, sunflowers also provide the benefit of being deep rooted, helping open up root channels in tough soils. For grazing mixes, a low seeding rate is probably best, but sunflowers can definitely be a good addition to a mix, in part because of additional benefits for pollinators, other beneficial insects, and songbirds.

Buckwheat. Among the fastest summer annuals to produce seed, buckwheat is a popular choice in diverse summer cover crop mixes. It has a much longer period of flowering than many other plants and is great for pollinator insects, including honeybees. Grazing animals do like eating buckwheat and it has some good nutritional properties, but it has a downside as well. The leaves and seeds of buckwheat have a phototoxin that can cause fagopyrism, which causes photosensitivity in grazing animals, especially lighter skinned animals. While fagopyrism is a bit less likely if used at low rates in cover crop mixes, there is still some risk. For that reason, it may be best to leave it out of grazing mixes or else be prepared to monitor livestock, especially light skinned animals, for any signs of the sensitivity. At the very least, buckwheat should only be used at a low seeding rate in a cover crop mix that is being grazed.

Okra. As a heat-loving southern vegetable that can grow 6 feet tall, okra is sometimes used in grazing mixes due to its ability to add a lot of biomass. It is best used in mixes rather than as a sole cover crop for grazing. The main downside is that okra's large seed pods can be a digestive issue for some livestock, especially smaller breeds.

Cautions with cover crop grazing

Despite the many benefits of cover crop grazing, there are two areas of caution to keep in mind. One is the potential toxicity from selected species of cover crops that can occur under certain growing conditions. The second is the use of residual herbicides prior to grazing.

Potential livestock toxicity issues from selected cover crops

Most of the cover crops described in this chapter are safe to use, particularly in mixes, but issues can arise that can lead to animal sickness or even death. Unfortunately, it can be hard to predict exactly when a problem will occur, but experience has shown when the probability of an issue is higher, so those situations are noted below.

Nitrates are a potential issue with a variety of cover crops and are most likely to reach dangerous levels during and after periods of plant stress, such as severe drought or frost. It's recommended to avoid grazing a cover crop for at least five days after a drought ends or after a frost. Using diverse plant mixes can also lower the risk from nitrates. Another strategy, when grasses are involved, is to manage the grazing so that livestock are primarily eating the upper parts of plants, since nitrates in grasses tend to accumulate more in the stems than the leaves.

Prussic acid is a grazing issue more confined to selected grasses, especially the sorghum family (plus a few non-grass species). Forage sorghum is the most likely to create a problem, but sorghum-sudan, and to a lesser extent straight sudangrass, can accumulate prussic acid. The issue is most likely to arise during a drought or after a non-killing freeze. As with nitrates, it's recommended to wait at least five days to graze after frost. During a drought, it's best to avoid grazing sorghum species. It can also be an issue early in sorghum growth, so waiting until the sorghum family plants are 18–24 inches tall can significantly lower the risk. Once again, diverse mixes can also greatly reduce the risks compared to grazing a pure stand of sorghum.

Bloat was mentioned as an issue with some legumes. This is easiest to deal with by having a diverse mix that includes grasses and when less than half of the mix's calorie portion is contributed by legumes. It can also help to wait until after dew comes off a field or after a rain has dried. If legumes represent a high percentage of the cover crops being grazed, introducing the livestock gradually to those legumes and feeding hay as part of the diet helps reduce potential for bloat issues.

Another legume toxicity issue is specific to hairy vetch. There is some data suggesting that hairy vetch can be toxic to cattle. More research is needed to more fully understand when this is an issue, but turning cattle into a pure stand of hairy vetch is definitely not recommended. Hairy vetch can also be a problem for sheep and goats, although cattle and horses seem most sensitive. A low percentage of hairy vetch in a diverse cover crop grazing mix may not necessarily be an issue, especially if grazing before the vetch has flowered, but the safest thing is just to avoid using hairy vetch for grazing until we learn more about this topic.

Among the Brassicas, the primary thing to watch out for is potential toxicity from high levels of sulfur, which can cause Polioencephalomalacia (PEM). This is not a regular problem but can be a potential risk when grazing cattle on a pure stand of Brassicas. It is best to keep the Brassica portion of the cattle diet to no more than two thirds of the diet.

A more general strategy to reduce health issues when starting cover crop grazing, especially if the livestock are coming off hay or poor pasture and the cover crops are lush, is to limit the portion of their diet coming from the cover crops during the first several days. This can be done by limiting their access to the cover crop and feeding some hay as part of the diet, until they adjust to the rich cover crop forage.

Concerns with residual herbicides in fields with cover crops for grazing

As most farmers are well aware, "the label is the law" when it comes to herbicide use. A number of residual herbicides used on commodity crops list multi-month periods before forages, including cover crops, are supposed to be planted and used for forage (whether for grazing, as hay, or other uses). These label guidelines should be followed. To avoid any legal issues, residual herbicides being considered for a field should be evaluated for their schedule impact on the desired grazing plan. In some cases, an alternative residual herbicide that doesn’t restrict grazing or a weed control strategy that avoids residual herbicides will be needed to allow cover crop grazing to proceed in the desired time window.

Summary on maximizing benefits for cover crop grazing

While there are a variety of ways to use cover crops for grazing, some general tips to keep in mind are summarized here.

1. Choose appropriate cover crop species that are safe for grazing with good biomass.
2. Increase seeding rates when relevant, particularly with winter cereals, but balance the seeding rates in mixes so that one species doesn’t crowd out other desired species.
3. Lengthen the cover crop growing period to achieve more biomass for grazing.
4. Move the grazing animals regularly (use management-intensive grazing practices).
5. Have a plan for your water supply and fencing, and evaluate virtual fencing as a tool.
6. Consider adding a small grain to the crop rotation so that it’s easier to fit in diverse summer cover crop mixes, adding additional grazing opportunities in the rotation.
7. Pay attention to management considerations that affect animal health and be sure to evaluate residual herbicide labels and plans.

CHAPTER 13

Use of cover crops in organic crop production

Cover crops have long been an essential tool in organic crop production systems, particularly for helping combat weeds and boosting soil fertility. Organic farmers of all sizes, ranging from small urban vegetable farms on a quarter acre, up to multi-thousand acre organic row crop farms, are using cover crops. Most organic certifiers recommend cover crops as a tool to achieve greater diversity in the crop rotation.

This chapter addresses some of the unique aspects of using cover crops in organic systems versus how they are managed in conventional crop production. Management of cover crop termination, species selection, cash crop planting methods (including planting green), and procuring organic cover crop seed are all discussed here.

One of the biggest differences for using cover crops in organic versus conventional systems is the method of termination. Especially with row crops, a high percentage of conventional producers rely on chemical termination of any over-wintering cover crops. With organic production, finding the right termination approach is important to successful cover crop use. Method of termination definitely depends on scale of operation and whether tillage is an option for termination.

Options for termination

Winter kill termination. Some new users of cover crops in organic systems will gain familiarity with them by starting with species that are killed by cold conditions. This can include summer cover crops like buckwheat or millet that are killed by the first fall frost, or fall-planted covers like oats or radishes that will be killed by temperatures in the low to mid-20s F. (Keep in mind that in southern latitudes these species may overwinter.) Use of winter-kill cover crop species prevents the need for any spring action to terminate an overwintering cover crop, but has the downside of less erosion control, a shorter period of root growth to feed soil biology, and less control of spring-emerging weeds. It's best suited for situations where spring cash crops are early planted, typically ahead of emergence of summer weeds. However, for overwintering cover crops, plans for cover crop termination are needed, as discussed below.

Roller crimper termination. These devices have become a popular option for some organic farmers to terminate overwintering cover crops. As described in the equipment chapter of this book (Chapter 9), roller crimping involves using a roller with fluted metal edges that can crimp the stems of living cover crops, breaking the vascular tissue in the stems (the xylem and phloem). Roller crimpers are now available in a variety of sizes, with the most common being 8–10 foot wide units that mount to the three-point hitch of a tractor. Larger folding units that can cover more ground are available. Smaller roller

Example of a cover crop crimping attachment for a BCS walk-behind tractor.

crimpers are available for small tractors or for walk-behind units like BCS tillers. Walk-behind roller crimpers have even been used in high tunnel systems.

The use of roller crimpers provides a relatively effective way to terminate covers without chemicals and without disturbing the soil. The rollers can also aid weed control by creating a thick mat of cover crop residue on the soil surface that can reduce weed emergence, keep the soil cooler, and prevent soil erosion. Some farmers have tried using rollers alone and this can work in some situations, typically with winter cereals that have headed out, but the action of the crimping metal edges usually improves kill of the cover crop plants.

It's important to note that successful use of roller crimpers requires some planning and being prepared to adapt to cover crop growth stage and weather. If the ground is soft from recent rain, it may be necessary to wait on using the roller crimper until the ground is firmer, which improves the crimping action of the roller. The stage of growth of the cover crop can make a significant difference. Usually, the more mature the cover crop is, the easier it is to terminate with a roller crimper. For example, cereal rye that is only a few inches tall would be difficult to kill by roller crimping, but bigger rye plants, especially after pollination starts, are much easier to roller crimp successfully.

Other challenges can involve having an excessively thick growth of cover crops where the crimper kills only the upper layer of plants while plants lower in the rolled layer survive. This can happen when the crimping edges don't come in direct contact with some of the stems. In those cases, a second pass of the roller crimper may be needed and/or more weight added to the roller crimper unit. Most roller crimpers have the option of adding fluid to the roller to give it more weight, such as water or an antifreeze solution. The advantage of antifreeze is that it is less likely to expand in cold temperatures and crack the roller; water used for weight should be drained from the roller before freezing temperatures occur. Concrete blocks or other heavy objects can potentially be added to the roller crimper frame to give additional weight if needed.

It's important to plant cash crops in the same direction as the roller crimping action. Early advocates of roller crimping preferred front-mounted tractor units, and that does have some advantage, particularly being able to have the planter unit mounted after the tractor and do both the roller crimping and planting all in one tractor pass. (Similarly, some companies sell smaller roller crimpers that can mount right onto a planter frame.) However, it is more common today to see roller crimper units behind the tractor, and the roller-crimper termination is done with a separate tractor pass after cash crop planting is done. More and more, farmers are planting their cash crop into a still-standing cover crop, called "planting green." Among other benefits, planting into a standing cover crop reduces the amount of cover crop stems that get pushed into the planting furrow.

As farmers and researchers have experimented with roller crimpers in organic systems, the timing of planting versus using the roller crimper has become a frequent source of discussion. Erin Silva, an organic farming specialist with University of Wisconsin, is among the leading researchers evaluating whether roller crimping can be done even after the cash crop has emerged, with a particular focus on soybeans. She has found there can be an advantage to planting

Example of a tractor set up with a front-mounted roller crimper and a row-crop planter attached to the rear of the tractor.

organic soybeans into cereal rye in Wisconsin that is at the boot stage and then waiting two to three weeks before running the roller crimper, typically when the rye is past anthesis (pollination stage). This allows the rye to provide greater biomass and more effective weed control, and the soybean seedlings seem tolerant of the roller crimper if they are still at the V1 to V3 leaf stage.

Organic vegetable producers have additional considerations for when to plant in relation to roller crimper action. If using a mechanical planter pulled by a tractor, the planting green approach followed by roller crimping may work effectively. If using a transplanter, usually the cover crop is rolled down first. Hand planting or using a walk-behind push planter can be challenging when cover crop residue is heavy, so some method of mechanical residue clearing might be required to ease planting.

Another option for reducing cover crop residue in the planting zone of a vegetable crop is to use alternating rows of a fall cover crop species, such as radish, that winter kills and leaves behind bare strips in the spring (called "biological strip-till"). The radish can be alternated with a winter cereal, and the winter cereal will provide some continued living roots and soil erosion prevention for months after the radishes die.

Mower termination. As noted in the equipment chapter, termination of cover crops by mowing can be done but requires careful planning and timing. It is almost always ineffective if the cover crop is still in the vegetative stages, as mowing at that point is like mowing a lawn—the cover crop will just grow back. However, most cover crops can be killed by a mower if they are far enough along in reproductive development and the mowing is done at a low enough height. Just be aware that even winter cereals that have started pollinating may bounce back if mowed too high and given a favorable rain after mowing. It is best to mow cover crops that are well into reproductive growth and as close to the ground as possible to get a successful mechanical kill.

Besides the issue of getting complete termination, mowing cover crops can have the challenge of leaving behind lumpy piles of residue. Rotary "brush hog" type mowers are generally the worst in terms of leaving uneven residue. A flail mower or sickle bar mower will do a more even job of laying down the residue. A good sickle bar mower can approximate the appearance of a field that has been roller crimped, but may leave an uneven distribution of biomass if the cover crop has extensive growth. Flail mowers are usually the best mower option for even distribution of residue but have a higher horsepower requirement per foot of row and are more expensive to buy than other mower options and roller crimpers.

Mowing is most likely to be used when a roller crimper is not available and the area of cover crops to be controlled is relatively small. As with using a roller crimper, mower termination does have the advantage of avoiding soil disturbance, unlike tillage termination.

Tillage termination. In past decades and centuries, cover crops were terminated through tillage. "Green manure" cover crops like clovers were typically plowed into the soil, burying most of the cover crop residue and leaving a relatively bare soil surface that could easily be planted with the cash crop. This system provided some biological fertility to the soil, especially the nitrogen provided by legumes, but left the soil subject to erosion during the weeks between plowing and cash crop establishment. In the current era, moldboard plowing of cover crops is uncommon, and indeed few moldboard plows are still found on farms, including organic ones. When tillage termination is used, mulching methods that leave a fair amount of cover crop residue on the surface are more common. Examples include using a disk, vertical tillage tool, rototiller, or other slicing type of tillage instrument.

As with mowing and roller crimper use, the timing of the mechanical termination action can be important. For many cover crop species, aggressive tillage such as rototilling can typically terminate the cover crop effectively when the cover crop is at an early growth stage. If a lighter tillage action is preferred, such as a light disking, it may require a couple of tillage passes or waiting until the cover crop is bigger, even in a reproductive stage, to get successful termination. However, disking a fairly sizable cover crop can in turn lead to a problem where a lumpy field occurs with large root balls from the mature cover crops, not to mention potential mounding of cover crop surface residue. Many first-time users of cover crops who have tried tillage termination of mature cover crops have been unhappy with the results. As with other methods, it is important to experiment, plan carefully, and adjust to conditions to make tillage termination work reliably and still have a good seedbed for planting.

Organic weed control spray products for termination. There is a big need in organic farming for National Organic Program-approved herbicides that can provide broad-spectrum control of annual plants, including cover crops. Concentrated vinegar is probably the most commonly used spray product at this time, but it is generally only effective when the weeds or cover crops are very small, and even then may not provide a 100% kill. Research is underway on additional organic herbicides that may be helpful, but it is difficult at this time to recommend an organic spray product that will provide consistent termination of cover crops, particularly if they are more than a couple of inches in size.

Flame termination. Conventional farmers sometimes talk of using a spring herbicide to "burn down" weeds or a cover crop. When organic farmers talk about burning down some plants, they are more likely to be talking about propane-powered flame weeder units. Flame weeding has its place in organic crop production, providing a way to desiccate undesired plants in a field without needing to do tillage. Of course, if the cash crop is already growing, the challenge is to avoid overheating or burning it. Usually, this is achieved by metal shielding that protects the rows of cash crop plants. However, for cover crop termination, the goal is generally to terminate all of the cover crop plants, meaning that the flaming needs to be done before the cash crop is planted, or at least before it has emerged. There are situations where this can be done, but the risk of igniting leftover crop residue from the previous year in a no-till situation is a real concern that greatly limits the use of this approach on a large scale.

Grazing termination. Keith Berns, a Nebraska farmer and co-owner of Green Cover, a cover crop seed company, has talked about the use of grazing to terminate cover crops as the holy grail of cover crop termination. If livestock are part of the organic system, this could be an approach to experiment with as a means of organic termination of cover crops. The idea is to take advantage of both soil health improvements from the grazing animals and the profit from the grazing, while getting the grazing livestock to do the work of termination. It sounds easy enough, but in reality, it's much like trying to use a mower to terminate, except the livestock may not be as consistent in "mowing" everything down as a machine might be. Just as with mechanical mowing, the cover crop needs to be reproductive to have the best chance of killing it with grazing. However, if the cover crop gets too mature, lignin builds up, palatability declines, and the livestock are usually much less interested in eating it. The way to potentially overcome this is to graze as intensively as possible, with a high stocking rate in a small area. Virtual fencing may be a tool that helps make this intensive grazing more feasible from a labor standpoint. As with other approaches here, experimentation on a smaller scale is recommended before attempting to use grazing for large-scale termination of cover crops.

Small scale termination. Horticulture producers on small acreage have used cover crops for years, but have typically had to rely on mechanical methods for termination, particularly mowing and/or rototilling. Rototillers work great to incorporate small or modest amounts of cover crop residue, but the tillage action can also spur weed growth, and is negative for soil health. On a really small scale, such as urban farms or high tunnels, it may not be viable to invest in a roller crimper or other mechanical control methods that allow no-till production (though a used push mower can be an inexpensive option). An emerging no-till alternative for termination of cover crops in these settings is to use a removable, light-blocking fabric such as tarps, black plastic ground covers, recycled billboard vinyl, or even cardboard on really small plots. The ground layer is left in place for 2-3 weeks until the cover crop is completely dead. In some cases, it may help to water the cover crop before or during coverage to make sure it's growing enough to get completely terminated by the light-blocking fabric. This approach can be particularly helpful in vegetable operations when various strips need termination at different times. However, there is growing awareness of the harm that plastics create in the environment, so carefully consider how to manage the plastics appropriately, or better yet, the use of alternatives.

Does planting green work for organic systems?

The approach of planting into a cover crop that is still green and alive has become significantly more popular among conventional farmers. As many as half of these farmers have tried planting green in some fields. As noted earlier, some organic soybean farmers are also planting green, usually into a winter cereal such as cereal rye, to get extra weed control benefits and maximize soil health benefits from letting the cover crop grow for longer. Cotton and certain other cash crops could be handled in a similar way for planting green.

Corn is somewhat more of a challenge for planting green in an organic system, especially for cereal rye or other winter cereals. The issue to overcome is potential nitrogen tie up from the winter cereal. Conventional row crop farmers have the option of planting corn while the winter cereal is still small and then immediately spray terminating, but at that cover crop growth stage a roller crimper or any other mechanical control method is not effective. Waiting for the winter cereal to get big enough for mechanical termination then creates a situation where soil nitrogen is being tied up, and some extra source of nitrogen at corn planting is needed. That could come from fish emulsion or other liquid organic nitrogen that is added near the corn row. Alternatively, the cover crop can be planted in the biostrip till approach described above, such as using radishes that winter kill where the corn row will be planted, alternating the rows of radishes with rows of winter cereal cover crop. Planting into those winter-killed strips is not quite a true planting green approach but it still allows for some green cover in between the rows that can then be terminated with a roller crimper.

Vegetable crops are perhaps even more challenging to plant green, but for certain species of vegetables the approach might work. The type of vegetables that will be more likely to work with planting green are larger seeded vegetables with vigorous early growth that can be seeded an inch or so deep with a planter (e.g., green beans). Experimenting on a small scale is advised before attempting any larger scale methods of planting green with any cash crop, including vegetables.

Selection of species

With over 40 species of cover crops for sale, there is much for an organic producer to consider in choosing which ones to use. Without a doubt, cereal rye is the most popular cover crop for both organic and conventional producers, given its winter hardiness, ability to be planted late, and extra weed control ability. However, organic producers have reason to consider a variety of cover crops for different situations, including cover crop mixes. Legumes in particular have great importance for organic producers, given their ability to provide biological nitrogen fixation. To get full advantage of legumes' nitrogen fixation, they need to be allowed to grow well into reproductive growth, which can mean delaying planting of some cash crops like corn.

Among the legumes, the big three for cool-season cover crop use on organic farms are hairy vetch, crimson clover, and Austrian winter peas. Hairy vetch provides good spring weed control and can be used farther north than the other two species, but with hard seed that can lead to volunteer plants in future years, hairy vetch has limited appeal for some organic growers. On the positive side, new varieties of hairy vetch with soft seed are on the horizon, and buying year-old hairy vetch seed can greatly lessen the hard seed fraction. In the southern half of the U.S., crimson clover is the most popular cool-season legume cover crop. For summer legumes, cowpeas and sunn hemp are frequently used to help provide nitrogen, such as after small grains, potatoes, or other early season vegetables.

Using mixes of cover crops that include legumes will provide some nitrogen fixation, but not as much as a pure stand of legumes. To optimize nitrogen production in cover crop mixes, be sure to favor the legume fraction of the seed mix, as too much in the way of grass cover crops can suppress legume growth.

Another species selection factor for cover crops in organic systems is the potential of certain cover crops to provide a disease to a following cash crop. While this is not a common problem, it can occur, and an organic grower may not have as many fungicide options for dealing with that disease as a conventional producer. It helps to have a rotation of cover crops and cash crops that alternates the plant family being used. For example, if planting corn, it is best to avoid using only grass cover crops, or if planting a Brassica cash crop, preferably avoid using a Brassica cover right beforehand.

It may be difficult to completely avoid having the same plant family planted back-to-back, but having a long-term crop rotation that uses multiple plant families and occasionally uses cover crop mixes instead of only single species can be a good overall strategy. Organic farming guidelines usually require diverse rotations in any case, which helps with reducing potential for disease buildup in fields.

Finding organic cover crop seed

As cover crop acreage has increased in the U.S., the supply of cover crop seed has also improved, and more species of cover crops are now available as organic seed. However, many of the less common cover crop species may be hard to find in organic form, and particular varieties of even common cover crops may not be readily available in organic form. Ordering seed early and reviewing offerings from multiple seed companies is a good way to ensure the desired seed can be obtained in organic form. If purchasing cover crop seed from another farm, make sure they have appropriate documentation of organic production methods.

If a particular species of cover crop is needed and is not available in organic form, check with the farm's organic certifying organization to confirm that non-organic seed can be used in that situation. Such use of non-organic cover crop seed may be allowed if no organic version of the species is available, but it's best to get that approved ahead of time to avoid having issues with maintaining organic certification for a field.

Where legumes are being used, be sure to obtain appropriate inoculum for mixing with the cover crop seed in order to achieve nitrogen fixation, especially in fields where that particular legume and inoculum have not been used recently. Most seed companies that sell cover crops can provide inoculum for legumes.

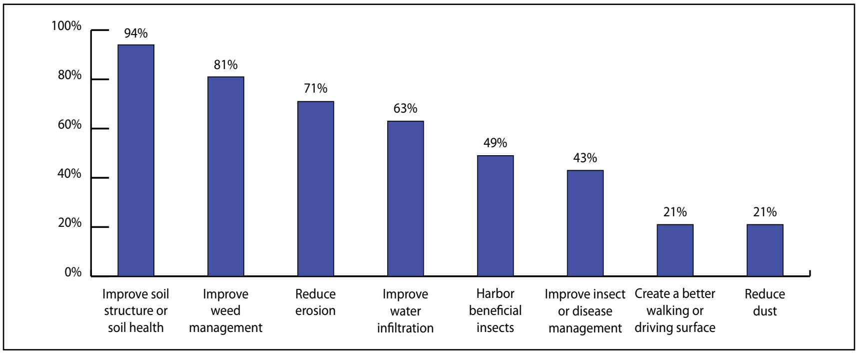
Planting organic cash crops into cover crops

From an equipment standpoint, seeding row crops into cover crops is largely the same for organic and conventional systems, keeping in mind caveats for termination such as terminating early when conditions are dry and avoiding nitrogen tie up with cereal rye and other winter cereals. The one notable difference is that while a conventional farmer can focus on making a seed furrow without being overly concerned about triggering weed emergence, it is of greater concern for the organic producer. While one might get great weed control from cover crops between the rows, this might be offset by significant weed growth that is triggered by furrow creation. The action of soil disturbance when creating a furrow exposes some weed seed to light and can create a race between the cash crop and weed seeds to see which will establish faster and cause competition for the loser. Ideally, organic row crop planting happens with minimal soil disturbance and most cover crop residue left in place. That's why planting soybeans green into cereal rye is a popular approach, because the rye helps suppress any weeds that might come up from the furrow disturbance.

CHAPTER 14

Cover crops in horticulture operations

While cover crops are often associated with large-scale row crops like corn and soybeans, in the modern farming era they first gained traction among horticulture producers, especially vegetable farmers. For vegetable producers, cover crops have served not only to help hold soil in place and improve organic matter, but also as a key method of weed control. With expanded use of cover crops in recent years, their benefits for pollinators, soil health, and rainfall infiltration are also becoming driving forces in adoption. As shown in the figure below, there are a wide range of reasons that horticulture producers use cover crops.



The primary reasons that horticulture producers used cover crops, according to data from the 2019-2020 SARE/CTIC National Cover Crop Survey.

The species of cover crops used, timing of planting and termination, and relative use of cover crop mixes all vary widely by horticulture crop, farm, and region. For example, a vegetable farm may use cereal rye mixed with vetch as winter cover crops, while also making use of warm season cover crops like buckwheat and millets after early vegetables are harvested. If a farmer anticipates not using a plot of ground for a long period of time, it's becoming increasingly common to use high biomass mixes of cover crops to improve soil health and restore soil fertility.

Termination of cover crops in horticulture operations often introduces different wrinkles than with large-scale row crops. For vegetable operations that may have many different vegetable species growing next to each other, spraying a herbicide to terminate a cover crop may not be an option due to the potential for drift to affect nearby vegetables. For perennial crops, herbicide drift is also a serious concern, leading to most orchards, vineyards, and berry crop operations to use perennial cover crops that don't need termination.

In general, horticultural use of cover crops can be split into annual cash crops on farms with vegetables and/or annual fruits, and perennial horticultural crops like apples, grapes, nut trees, berries, and even perennial herbaceous crops like herbs, asparagus, etc. In most cases, the annual horticulture crops get used with annual cover crops, and perennial horticulture crops get used with perennial cover crops. The remainder of this chapter discusses cover crops in these annual and perennial systems as separate topics and approaches.

Horticulture operations with annual crops

With the wide range of annual horticultural crops that one may grow on a farm, considering plant families and the overall crop rotation is a good place to start in planning for cover crops. For example, if Brassica cash crops are being grown, like lettuce, cabbage, or cauliflower, it's best to avoid using a Brassica cover crop like radishes right before the cash crop. Using a grass and/or legume cover would be a better choice. Since most vegetables are broadleaves, using some grass cover crops in the rotation can be helpful to break up certain disease and insect cycles.

Matching up the timing of when the cover crop needs to be winding down before planting an annual horticultural crop is also a key factor. Regional cover crop councils have cover crop selector tools, such as from the Midwest Cover Crop Council, that can be used to help plan out timing of cover crop growth in the rotation. As noted in Chapter 5 on cover crop selection, evaluating when to use cool-season cover crops versus warm-season cover crops should be part of the planning process.

A good starting point is to fall-plant an overwintering cover crop, either a single winter cereal species (e.g., rye, wheat, triticale, or barley) or add in a legume with that winter cereal. For early planted vegetables like potatoes, peas and salad greens, early termination of the winter cover crop will limit spring growth of the legume, but the added plant diversity can help promote diversity in the soil microbial community. Where later planting dates are used for vegetables like green beans, tomatoes, and pumpkins, legume cover crops can become more helpful. Providing a longer spring growing season for legume cover crops can allow them to contribute in a meaningful way to the nitrogen fertility needs of a summer vegetable. In those situations, cutting back on the seeding rate of a winter cereal mixed with legumes will allow the legume to achieve adequate growth in spring.

Caution on cereal rye

Cereal rye, while a workhorse cover crop in many situations, needs to be used with a degree of caution where small-seeded vegetable crops are part of the rotation. The allelochemicals produced by rye are particularly impactful on small-seed broadleaf plants like lettuce and carrots. To reduce this problem, terminate the rye as early as possible in the spring, or better yet, use a different winter cereal like wheat. For other vegetable crops that have larger seed, like peas and beans, there may be no issue with the rye as long as it doesn't dry out the soil too much in late spring or tie up nitrogen in a way that affects non-legume vegetables (a potential issue with mature rye).

Seeding cover crops in annual horticulture operations

The size of the cover crop area to be planted will have a big impact on choosing a seeding method. If planting an acre or more, some method of mechanical seed distribution is best, either a small grain drill or broadcast seeder. Drones are getting more common for cover crop seeding and can be used in much smaller areas than planes or larger fertilizer spreaders. In plots under an acre in size, it becomes more viable to seed cover crops with some sort of hand broadcast

Buckwheat is growing as a temporary cover crop between other vegetables.

spreader, such as the type of hand crank spreaders sold in many hardware stores for broadcasting fertilizer or lawn seed.

Getting good seed-to-soil contact is important for germination. Light tillage may be needed before or after broadcasting cover crop seed, especially larger seed such as winter peas or oats; following up the broadcasting with a weighted roller can help press the seed into the soil. Smaller seeded cover crops like radishes or clovers can more easily be broadcast-established with no soil disturbance, but timing the broadcasting before rain or applying moisture with irrigation will really help with establishment.

Use of a grain drill on larger plots is recommended to get the best establishment with cover crops. For those who have a tractor but don't have a drill, it may be possible to rent one at low cost from a local soil and water district office (some of those offices have drills and others do not, so check around).

Temporary in-season covers in vegetable operations

Cover crops are used in a variety of ways in horticultural operations, especially vegetable production, but one of the most common uses is as a temporary cover during the growing season. For example, after an early harvest of potatoes, vegetables, or greens, it's common to see fast growing summer covers like buckwheat or foxtail millet planted. Both are easy to establish and manage, and do a reasonably good job of suppressing weeds while providing some soil protection and improvement. Buckwheat's prolonged flowering period is especially advantageous for pollinators.

When a cover crop is needed in spring before planting a summer vegetable, there are a variety of quick-growing cool season cover crops that can be used. Particularly favored are some of the annual legume cover crops like crimson clover and Austrian winter peas. Both do well when planted in early spring and can produce a reasonable amount of nitrogen with two months of growth before making way for summer vegetables. Crimson clover is more easily broadcast-established than Austrian winter peas, but the latter can be broadcast if they are worked into the soil with a rake, a tractor roller or other method. All legume cover crops should be seed treated with inoculum to ensure nitrogen fixation takes place.

Terminating cover crops in annual horticulture operations

As with seeding, the termination approach for cover crops depends in part on the size of the area to be terminated. The species of cover crops is also a factor. Of course, any species that winter kill don't need termination, and perennial cover crops like white clover or red clover are planted for a multi-year period and shouldn't need termination. For annual cover crops that do need termination, most mid-sized to larger-scale horticulture operations are using tractor-mounted mechanical control methods. Many of these termination approaches are outlined in the chapter on cover crop termination, but in the context of horticulture production, they are also briefly described here (and similar termination information is provided in the chapter on organic cover crop use).

Tillage. While less popular as a termination method than it used to be, tillage remains the most common way cover crops are terminated within vegetable operations and selected other horticulture operations. Rototilling is often used as a quick way to both terminate and incorporate cover crop residue, allowing faster incorporation of cover crop biomass into the soil rootzone. The tillage also serves the purpose of helping prepare a seedbed for planting vegetables or other crops. Unlike other mechanical control methods, tillage usually controls cover crops in a variety of growth stages. However, such tillage has a negative impact on soil health and leaves the soil much more subject to erosion until the next horticultural crop is well established. Thus, tillage has gradually become less common as a method of cover crop termination, although it is still frequently used. Besides rototilling, disks, small plows, and other tillage instruments are sometimes used for tillage termination. When opting for tillage, give consideration to how much residue will be left on the soil surface by the chosen tillage method. The longer it will be until the next crop is planted, the more residue should be left on the surface (if possible). If there is concern on small scale plots that tillage will leave lumps of cover crops in the way of the next cash crop planting, some form of mowing can be done to chop up residue before tilling.

Roller crimping. While tillage has declined in importance for cover crop termination, the use of roller crimpers has been gradually increasing. Roller crimpers are generally an effective termination tool, performing best when the soil is dry and biomass is moderate. Cover crops usually need to be in the flowering or heading stage for effective termination by a roller crimper. For example, winter cereals only a few inches tall will not be consistently controlled by roller crimpers. Roller crimpers are available in a variety of widths for use on either the front or back of tractors. At least one manufacturer has made a small crimper for use with a walk-behind BCS tiller that can be used in smaller plots or even in high tunnels.

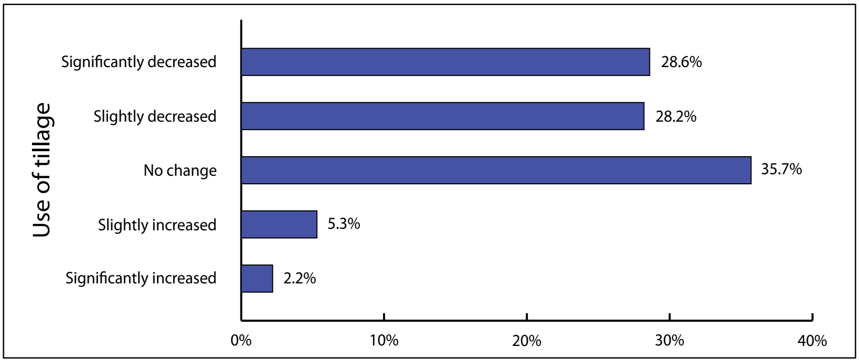
Mowing. The use of a mower is a common method of cover crop termination in horticulture operations, and perhaps is the most versatile across a range of operation sizes, since you can use anything from a push mower to a large tractor-mounted mower. Flail mowers make for the most effective tractor-mounted mowers, as they are able to chop up cover crop residue more finely and leave a more even layer of residue. Less expensive brush hog (rotary) mowers can be used but are likely to leave the cover crop residue lumpy, creating problems for seeding the horticulture crop. Sickle bar mowers can be used but may leave lumpy residue in high biomass situations. Regardless of the mowing method, waiting until the cover crop is flowering and then mowing as close to the ground as possible is often necessary to getting a complete kill of the cover crop. A cover crop that is still vegetative when mowed will typically rebound and keep growing, much like mowing a lawn. Other advantages to letting the cover crop grow longer before mowing are getting flowers that benefit pollinators, better weed control, and of course more cover crop biomass to improve the soil.

Spray termination. Terminating cover crops with herbicides is occasionally done in horticulture operations, but usually only large-scale ones due to the risk of herbicide drift onto adjacent crops, and from a desire to reduce herbicide use in many of these farming operations. If a herbicide is to be used, paying attention to wind direction and speed is critical to avoid any herbicide drift issues that could damage other crops or have effects on nearby people and animals.

Tarping. For small-scale cover crop termination (plots with hundreds but not thousands of square feet), some horticulture operations have gone to using tarps, cardboard, or other temporary covers that can terminate a cover crop in 2 to 3 weeks' time. Light-blocking fabrics or other materials are normally used. If clear plastic is used, the cover crop will still receive enough light to keep growing, unless temperatures are particularly high under the plastic. An advantage of using such fabrics, besides saving money on equipment and dealing with sprays, is the ability to do no-till planting (also possible with mower termination or roller crimpers). Managing any plastics in a way that minimizes environmental impacts is advised.

Impact of cover crops on use of tillage in horticulture operations

About a quarter of horticulture producers responding to the 2019-2020 SARE/CTIC National Cover Crop Survey said that they terminated cover crops with tillage. While the majority of producers used other methods of termination, the use of tillage by some farmers for cover crop termination has created an impression among some that tillage increases with cover crop use. This is actually not the case, as shown in the figure below. The same 2019-2020 SARE/CTIC survey showed very clearly that over half of horticulture producers reported reducing tillage after adoption of cover crops, while only 7% said they increased tillage (and most of those had just a slight increase in tillage).



Responses to the survey question, "How has your use of tillage in conjunction with using cover crops changed in recent years?". From the 2019-2020 SARE/CTIC National Cover Crop Survey.

Horticulture operations with perennial crops

A different set of considerations comes into play when using cover crops with the many types of horticultural crops that are perennial in nature, such as orchards, vineyards, berry plantings, etc. Most often, farmers will use perennial cover crops, so a cover crop planting may be in place for at least a few years if not several, and termination of the cover crop is not needed unless the ground cover is being rejuvenated.

Two big questions to consider with perennial cover crops are finding species that are not overly competitive with the adjacent horticultural plants, and finding species that have a growth habit suited to the management and harvest needs of that operation. For example, if nuts or other products that fall to the ground need to be harvested, then a cover crop that can tolerate mowing or is very low growing will be needed to avoid impeding the harvest of the nut crops. In a berry or vineyard situation, cover crops that are climbing, such as crown vetch, could become a problem by interfering with pruning and harvest of the horticulture species.

Ideally, a mix of two or more perennial covers would be used to improve biodiversity and functionality of the cover crop, but that may not be practical from a maintenance standpoint. Most often, perennial horticulturalists default to some type of perennial grass ground cover that can tolerate mowing as well as regular foot and machine traffic. Some grasses used in orchard and vineyard settings are cool season species but a few, such as native buffalograss, are warm season plants. It may be best to find a species that is not overly competitive when the horticultural crop is at the peak of its needs for water and nutrients. Other considerations are how the cover crop impacts populations of certain pests that could affect the horticultural crop, ranging from diseases and insects to voles and mice. Voles particularly like legumes but can still thrive in pure grass stands, especially if there is additional cover like mulch around fruit trees or grape plants.

Plant competition is a significant concern when choosing ground covers around perennial plants. The species best suited for foot and mechanical traffic and frequent mowing are of course the common turfgrass species, but most of these are quite competitive with other plants. Tall fescue and Kentucky bluegrass, both commonly used in lawns, orchards, and vineyards, are likely to slow the growth of any perennial plants they are adjacent to due to competition for water and nutrients. They can still be used, but it's best to keep these grasses several feet away from the perennial crops being grown.

Another consideration is native versus non-native species. Unfortunately, in most parts of the U.S., there are relatively few native species that are both readily available and well-suited for ground covers in orchards, vineyards, or berry production. Across the Corn Belt, one native option is a mix of buffalograss and blue grama grass; sometimes sideoats grama grass is added. A mix of 40% buffalograss and 30% of each of the other two species can be used. Sideoats

An Oregon vineyard with a white clover cover crop used between grape rows.

grama grass is a somewhat taller species, so if a shorter ground cover is desired it is typically left out of the mix.

Shade tolerance of potential cover crop ground covers should also be evaluated. While ground covers in vineyards and berry crops generally receive plenty of sun, for plantings in tree orchards, consider more shade tolerant species, or at least a mix of sun and shade tolerant species, with the shade tolerant species becoming more important as the trees mature.

On the following page is a table of some of the more common species used in orchards, vineyards, and berry plantings in the temperate areas of the U.S. (excluding the most moisture-limited areas). Some areas of the west and the Deep South will have other options that are better suited to local conditions. For example, subterranean clover (adapted to hardiness zones 7–10) has viability as a legume mixed with grass for more southern areas or California.

Plant species used as perennial cover crops (ground covers) in orchards and vineyards*

Species	**Hardiness zone****	**Sun/shade**	**General notes**
Buffalograss	3-10	Sun	Drought tolerant warm-season native
Blue grama grass	3-10	Sun	Drought tolerant warm-season native
Sideoats grama grass	3-10	Sun/some shade	Drought tolerant warm-season native
Orchardgrass	3-9	Sun/shade	Clump type grass, dwarf types available
Perennial ryegrass	3-8	Sun/some shade	Suited to wetter conditions
Redtop grass	3-8	Sun/some shade	Tolerates a range of soil moistures
Red fescue	2-7	Sun/some shade	Relatively drought tolerant
Sheep fescue	3-8	Sun/some shade	Relatively drought tolerant
Tall fescue	3-8	Sun/some shade	Drought tolerant, highly competitive
Kentucky bluegrass	3-9	Sun	Not as drought or shade tolerant
White clover	3-10	Sun/some shade	Low growing, not very traffic tolerant
Red clover	3-9	Sun/some shade	Mid-height, may only persist a few years
Alfalfa	2-9	Sun	May only persist a few years

**This list is not all-inclusive, as other species are sometimes used in certain areas, but it represents many of the more common cover crops used with woody horticultural crops. Other than the first three grasses listed, all the other species are cool-season plants that are not native to the U.S., but are well adapted to many growing regions.*

***Plant hardiness zones listed are for the species as a whole; specific varieties may have more or less hardiness than what is listed here, so be sure to research traits of any named variety being considered.*

Herbaceous perennial crops

Whereas woody crops can generally compete relatively well against herbaceous cover crops for water and nutrients, herbaceous horticulture crops may be less likely to do so, especially if the cover crops are taller than the perennial horticulture crop or if the cover crop is a perennial. Designing the right combination of perennial cover crop and cash crop is all about managing that competition and finding plants that are complementary with each other. Many of the ground covers listed in the table above can be considered, but keeping an adequate distance between the ground cover and the herbaceous perennial crop is important.

In this Michigan cherry orchard, the Kentucky bluegrass ground cover is kept well back from the trees to reduce competition from the grass.

CHAPTER 15

Leaving the land in better shape for the next generation

At the end of the most challenging decade American farmers had ever faced, Hugh Hammond Bennett, father of the soil conservation movement in America, penned the following words to open his seminal 1939 book *Soil Conservation*:

> In fifteen decades, Americans have transformed a wilderness into a mighty nation. In all the history of the world, no people ever built so fast and yet so well. This will be a land of liberty, they said in the beginning, and as they hacked the forest, drove their ploughshares deep into the earth, and spread their herds cross the ranges, they sang of the land of the free that they were making . . . . [yet] not mere soil is going down the slopes, down the rivers, down to the wastes of the oceans. Opportunity, security, the chance for a man [and woman] to make a living from the land – these are going too. It is to preserve them – to sustain a rewarding rural life as the bulwark of this nation, that we must defend the soil.

Just as Hugh Hammond Bennett recognized the critical need to prevent soil erosion from destroying the productivity of our land, today we are learning that soil health must be restored if our land is to remain productive for our children and our grandchildren to farm.

Many, many farmers have told me one of their top priorities is leaving the land in better shape than they found it, especially with the hope that one or more of their children will be able to farm and thrive upon the same land. For all of us, having healthy soils is essential to the prosperity and vitality of our nation. Leaving a legacy of better soil and better land is a goal everyone in agriculture can aspire to and contribute to. It's our collective goal of land care and legacy that I want to address in this final chapter.

Using a bulk density ring to get an intact soil sample as part of soil health assessment. Photo courtesy of Rick Koelsch, University of Nebraska.

As I've traveled across the U.S. visiting over two hundred farms in my work with the USDA SARE program, I've come to see the strong connection conservation-minded farmers have with their soil. It doesn't matter if they farm two acres of vegetables, 20 acres of fruit trees, 200 acres of pasture, or 2000 acres of row crops; no one wants to leave behind degraded fields and pastures or see precious topsoil washing away.

We are fortunate that these days we can take advantage of new soil health tests to evaluate how we are doing with maintaining and building the health of our land. More and more soils labs are offering soil health tests, allowing soil monitoring over time to tell us if we are headed in the right direction with our soil care.

If you are getting some soil health samples from a field, pull some comparative ones from an undisturbed fence line or long-term pasture to gauge how your cropping system is affecting the soil. Be sure to get guidance from a soil health expert with NRCS, Extension, or a trained soil health advisor in evaluating the results of the test. Look at a combination of soil health test results for things like active soil carbon, soil aggregate structure, soil microbial respiration, and other measures. Just like your doctor looks at several different health factors, such as cholesterol, blood pressure, body mass index, and blood workups, we need to evaluate several measures of soil health from a field to get a sense of the biological, physical, and chemical status of the soil.

When I think about where we're at with soil health today, I think that we are at the beginning of a new agricultural chapter in better understanding how to use practices like cover crops to regenerate the health of our soils and build resiliency in our farming operations. I think of farmers like Dan DeSutter from Indiana who has said a principal goal before he retires from farming is to rebuild his soil organic matter to the level it used to be at when plows first carved into the prairie soil on his land. His mindset is driven by his strong desire to leave the farm in a productive and prosperous state for his three sons to farm, just as he followed his father in farming.

I think of Ray Gaesser, a former president of the American Soybean Association who farms in Iowa. Ray has spoken regularly in meetings about how his terraces and no-till system were not proving sufficient to stop erosion in big rainstorms, and he found cover crops could help anchor his soils in place. The more he has used cover crops, the more he has seen the soil health improve. Ray also farms with a mindset of leaving the land better for his son who now farms with him. (Both Ray and Dan are part of the farmer profiles in this book – read their stories in the following section.)

And it's not just sons, it's daughters and nieces and nephews and in-laws and grandchildren coming into a farming operation where the productivity of the soil is so important to their short-term and long-term success. Even if no family member is engaging with the farm, what better legacy is there than to pass along productive farmland to the next generation? Just as the land has sustained all of us to date, we need the land to sustain those who come after us.

I titled this book *Cover Crops: Improving Soil Health, Stewardship and Profitability on the Farm* to emphasize how crucial it is that we have living soils. I was fortunate to be part of making a beautiful

Cereal rye cover crop protecting and improving the soil. Photo by Edwin Remsberg.

award-winning film called *Living Soil* that shares the stories of many farmers across the U.S. working to improve the health of their soils with cover crops. I'm glad to say this film has been enjoyed by over four million people at the time I write these words. It's free to watch on the internet; just do a search for "Living Soil Film" and you'll easily find it. If you are not yet convinced to try cover crops on a field, I think this film will inspire you.

My closing advice in this book for those who have yet to try cover crops is to start small. Just take a single field and plant a cover crop like cereal rye after harvest. Give it a real chance, plant the cover crop quickly after harvest and use a grain drill or other effective seeding method. Pick a cover crop suited to your area. If it fails to establish the first year, try again. The volunteer-led regional cover crop councils have tips online for cover crops to use in your area and suggested management approaches (do a search for Midwest, Southern, Northeastern, or Western Cover Crop Council to find their websites). There's also a wealth of information from the USDA SARE program (see www.sare.org/covercrops) and your local NRCS staff.

Find a farmer or two in your area or your state who has been using cover crops for a while and see what they have to say. You can find these farmers through your local NRCS, soil and water district office, Extension office, regional cover crop council, or by going to a local field tour or meeting on cover crops and soil health.

Ultimately, it's up to you, regardless of your role in farming, to help protect our soil and improve soil health. Cover crops are a key tool to help farms thrive and provide productive farmland for many years to come. I have found working with cover crops to be an enjoyable and rewarding experience and have had many, many farmers tell me they feel the same way. Today over 150,000 farm families in the U.S. are using cover crops in every region of the country. The land you work with can be green and healthy if you take the steps to get there. Read the stories of farmers from across the U.S. in the following profiles to learn about why they use cover crops and what they have experienced.

Farmer Profiles

David Brandt (Ohio)

Photo courtesy of Walnut Creek Seed

**In May 2023, after this profile was written but before the book went to press, David Brandt was in a traffic accident and died as a result of his injuries. His passing was a huge loss to the conservation movement in the U.S. I hope sharing his story will help his efforts live on, as they have through many other stories and articles about him. Without question, he had a huge impact on the adoption of cover crops and the soil health movement in the U.S.*

Dave Brandt farmed row crops on about 1,000 acres in Ohio, southeast of Columbus. He was primarily a corn, soybean, and wheat producer over the years. In recent years, he also grew various small grains for the cover crop seed market. His family farm has been oriented toward conservation for many decades, implementing their first no-till fields in 1969 and, within a few years of that, converting to 100% no-till.

During 1979, one of his early years of farming, he noticed corn yields were declining and thought legume cover crops could help, so he tried them and found they did help bring his soil back to life. He used hairy vetch at first, then later used yellow sweet clover on fields going into that era's USDA "set-aside acres" program. He tried various clovers in the 1980s, and started using radishes and winter peas in the late 1990s.

Dave was widely known as being one of the first farmers to make extensive use of cover crop mixes, being an early advocate of diverse "cover crop cocktails" after winter wheat harvest. Dave said he had found that a diverse, high-biomass summer cover crop mix really helps improve the soil because the cover crops planted mid-summer have a long window to grow. He also noted that some of the species in his summer cover crop mix, such as sunn hemp, cowpeas, and sunflowers, can get deep roots. He saw roots five feet deep in the fall from those mixes.

Using a small grain followed by summer cover crop mixes as part of a rotation with corn and soybeans lead to faster soil improvement, in Dave's experience. He observed that it can take up to three times longer to see equivalent soil health improvement when doing only a corn-soybean rotation with covers.

Although he continued to tweak his approach, his three-year crop rotation and cover crop strategy at the time of his interview for this book is outlined below.

After corn harvest, he planted cereal rye, often with balansa clover and rapeseed or radishes. If he was seeding the covers fairly early after corn harvest, he added radishes. If seeding later in the fall, he switched out the radishes and used rapeseed instead.

The next spring, he planted soybeans and then, after soybean harvest, a winter-hardy small grain. In years past that was usually winter wheat, but in more recent years he had started growing a greater diversity of small grains, including some artisan wheats. For the cover crop seed market, he also used spelt, cereal rye, or sometimes winter wheat, grown as single species that was harvested mid-summer. Then, after harvesting the small grain (winter cereal), he planted an 8- to 12-way cover crop cocktail mix, drilling into the cereal residue.

His summer cover crop cocktail mixes included both warm-season and cool-season species. Typical warm-season species were sunn hemp, cowpea, sunflower, buckwheat, and sudan, or sorghum-sudan. The cool-season species were typically crimson clover, hairy vetch, winter pea, cereal rye, barley, flax, and Brassicas. The warm-season species grew vigorously in summer and early fall, assuming adequate soil moisture was present. The cool-season species emerged in the summer but stayed small under the canopy until fall, then grew more vigorously in the cool weather of fall and early spring. While the warm-season species died with the first frost, the cool season species could keep growing for weeks longer, sometimes until temperatures were as low as 20°F, depending on the species.

Normally he planted 100% of his corn and soybean fields to cover crops, but he said that about every one year out of four, weather prevented him from being able to plant all acres to cover crops.

Cover crop seeding method

Dave was a big advocate of using a drill to plant cover crop seed. To get over more acres in less time, he invested in a 30-foot KUHN Krause drill, which he found to be very effective for no-till seeding. It allowed him to plant quickly, and he usually had time to do some cover crop seeding for neighbors.

When doing mixes, Dave didn't have too much trouble with seed segregation, but occasionally noticed some seed segregation if the seed had been mixed for a long time. He noted that sunflower seeds in particular would sometimes come to the surface and need to be stirred back in.

Over the years, Dave learned that keeping his cereal rye seeding rate relatively low at about 20 pounds per acre allowed for more growth on the legumes in the mixture.

Termination and spring planting of cash crops

With soybeans, Dave normally used a planting green approach, drilling the soybeans into the still-living cover crop. After planting, he used a roller crimper to terminate the covers. Ideally, he rolled the cover crops to terminate them when the cereal rye was about two-thirds in bloom and rapeseed/canola was producing seed pods. He tried to use the roller crimper before the soybeans emerged. He tried rolling when beans are already up, but found that if the beans were in the second leaf stage, the roller could break some of the soybean seedlings. He found that he could roll soybeans in the first leaf stage and achieve satisfactory results.

One reason he sometimes waited on roller crimper termination was if it was a wet spring, in order to let the cover crops pull down more soil moisture. When planting green, he found the living cover crops helped keep insects away from soybean seedlings.

About 70% of the time, his planting green approach worked well to manage weeds, and in the other 30% of cases, he did a post-emerge application to handle the weeds. Normally, he did not apply a residual herbicide or any pre-plant herbicides. He commented that his beans and corn were non-GMO, which gave him a market premium.

Dave wanted to maximize cover crop benefits for corn, so he planted corn later than most of his neighbors. He typically waited to do corn planting until around May 20, letting the soil warm up. He felt he had less insect pressure, in part because the corn pops up fast in the warmer soil. That fast corn seedling growth helped him reduce

David planting green into a living cover crop mix. Photo Courtesy of Walnut Creek Seeds.

potential problems with slugs. He found some slugs in his fields, but the corn grew fast enough to escape major damage, and many of the slugs focused on eating the green cover until it was dead from termination. After corn (and soybean) planting he normally used his 20-foot I&J roller, and tried to do so quickly if conditions were dry. If the soil was damp, he might wait 4-5 days to let the cover crop help dry out the soil, which improved roller performance.

Another aspect of his spring corn management was that he used liquid starter fertilizer at planting time to give a little nitrogen boost to the corn. When the corn was knee-high, he applied a modest amount of additional nitrogen, adjusting based on the amount of legume growth.

Dave said he liked to let his cover crops reach the flowering stage in spring, in part because of all the beneficial insects attracted by the flowering cover crops. He noticed a lot of carabid (ground) beetles eating slugs and armyworm larvae, which he felt had helped reduce problems from those pests.

He discontinued purchasing commodity seed with insecticide treatments in about 2016 (unless it was a variety comparison test plot that had some treated seed). He also avoided buying seed that is fungicide-coated, preferring to avoid impacting the soil fungi. Planting his corn and beans later helped reduce the need for seed treatments.

Dave transitioned to using types of corn and soybeans that took less time to mature, which allowed him to plant his cover crops earlier in the fall. The shorter-season varieties he used were still yielding well, and allowed him to harvest soybeans 7-10 days earlier and corn 4-5 days earlier, despite planting relatively late in the spring.

Observed changes in soil health

Dave indicated that, after many years of no-till and cover cropping, he had significantly built up his soil organic matter, going from 1%-2% on rented ground up to 4%. His home farm, where he'd done these practices for decades, was even higher in organic matter–up to 8% in some locations.

The greater amount of organic matter and improved soil biology allowed him to cut back on the amount of fertilizers he used. He found he could get by without needing to apply phosphorus or potassium to small grains, and applied only a modest top-dress application of 30 pounds of nitrogen per acre on small grains in the spring. He also reduced phosphorus and potassium applications for soybeans and corn. His nitrogen program for corn varied based on legume cover crop growth, but he indicated that he generally used under half the nitrogen that his neighbors did to get a satisfactory corn crop. He liked to use the Haney test to help him determine his NPK rates.

Over the years, Dave noticed more soil organisms that were visible, like earthworms and soil insects, and also saw lab test results show more microbial activity.

A big benefit Dave cited was improved rainfall infiltration rates of up to 6.5 inches per hour. He mentioned how ground he rented that had been conventionally farmed would puddle for 4-5 days after a sizable rain; once those rented acres underwent his three-year, cover-crop-intensive rotation, that puddling started to disappear pretty quickly as rainfall infiltration increases substantially.

Soils on his farm were relatively high in clay content and had relatively shallow topsoil compared to other parts of the Midwest. Most of his fields, eroded from decades of previous conventional farming, had only 4-5 inches of topsoil. On fields where he had done decades of no-till and cover crops, not only was the A horizon darker in color, but he also had better soil structure with highly aggregated soil particles. The improved soils didn't have compaction issues, and he mentioned how easy it was to put a soil penetrometer in the ground.

In the exceptionally wet spring of 2019, Dave said he was able to plant his farm on his normal schedule in mid-May, whereas most of his neighbors were delayed on planting until June and many of them had to declare some fields prevent-plant (meaning they couldn't be planted due to prolonged wet weather, so they filed for crop insurance and left the fields idle that year).

Interestingly, Dave said that with the improved soil health on his home farm he hadn't needed to apply lime since the 1970s, with most fields testing at about 6.9 pH. He felt the cover crops elevate calcium, maybe in part because deep rooting helped pull up calcium from deeper parts of the soil. He was also putting on significantly less nitrogen, which avoided some of the pH-lowering impacts of common forms of nitrogen fertilizer.

Other impacts of his cover crop system

Dave documented that cover crops drastically improved his profitability. He summarized that his system has increased return on investment by 62%-65%. In 2018, he did a careful analysis and found it would take him only 107 bushels of corn per acre to break even due to his modest input costs (including the no-till benefit of having reduced machinery, fuel, and labor costs). He had a very profitable return that year from his corn crop of 192 bushels per acre. That same year, he calculated that his soybeans would only need to make 28 bushels per acre to break even, and his average soybean yield was 72 bushels per acre that year (this was on ground that Dave owns).

In dry years, cover crops really shined on Dave's farm, providing significantly more soil moisture. In the major drought year of 2012, when many neighbors had very poor yields, he still achieved 185 bushels per acre of corn.

Dave collaborated with university researchers who had used surface runoff flumes to determine that his no-till cover crop approach has greatly reduced loss of nitrogen and other fertilizers from his fields compared to a nearby conventional field.

He also worked with Rafiq Islam, a researcher at Ohio State University, to test the nutrient content of his grain versus that of conventionally produced grain. A number of nutrients tested higher in Dave's grain, which Islam attributed to the much greater soil health on his farm. They documented higher levels of protein in Dave's corn and soybeans, allowing him to get a premium from a nearby hog operation using his grain as feed.

When asked for tips he would give farmers who haven't started using covers, Dave said, "Start out by trying cereal rye seeded after corn harvest, and then plant soybeans the next year. You'll see a big reduction in erosion and also capture nutrients you would otherwise lose from the field." Dave added that he found the soybeans yields increased by 5-7 bushels per acre, easily paying the cost of cover crop seed. He believed most farmers could gradually reduce their fertilizer costs as well, cutting back on fertilizer rates by maybe 25% after a few years of cover cropping, depending on their soils and system. He also said farmers using rye will find that their soil tilth improves to the point where the planter will pull more easily through the field. Starting with cover crops can be a good way to transition to no-till, which can provide big savings on diesel fuel, labor, and equipment costs.

Donn and Chad Branton (New York)


Donn Branton on left, Chad Branton on right. Photos courtesy of the New York Corn and Soybean Growers Association.

Donn Branton farms with his son Chad in western New York, about 20 miles west of Rochester near I-90. They farm about 1,700 acres, half of which is corn and soybeans. They also grow cereal rye and oats for cover crop seed production and do vegetable processing. The vegetables vary by year depending on what contracts are available, but often include sweet corn, peas, snap beans, and most recently adzuki beans. They do not have livestock.

In 2016, Donn helped establish the Northeastern Cover Crop Council, which is a diverse group of farmers, researchers, educators, and agency and industry staff that share information on cover crops and provide conferences and other support to people looking for cover crop information. Donn has continued to serve on the executive committee for his regional cover crop council and recommends that other farmers check on information available through their own regional council. As mentioned earlier in the book, there are four of these councils in the U.S., for the Northeast, South, Midwest, and West.

The Branton farm has a long history with cover crops, dating back to the late 1970s when they were overseeding medium red clover into winter wheat and using it as a green manure crop. About 25 years ago, they began experimenting with cereal rye as a cover crop and liked how it worked after dry beans or other early-harvested crops. Donn admits that it took them a while to start to understand all the benefits they were getting from cover crops, but they could quickly tell the rye was helping to stop water erosion; later, the benefit of stopping wind erosion became apparent as well.

Starting in 1986, they began testing no-till corn on a small acreage, gradually adding more and more area. A decade later, in 1996, they bought a new 12-row planter set up for zone-tilling (a type of strip-tilling). At first, they focused on using the zone-till approach to plant corn. Then they started testing how conventionally tilled soybeans fared versus zone-tilled, and found the zone-tilled soybeans outperformed conventional ones. That led them to add sweet corn to the zone-till system, despite some initial lack of enthusiasm from their sweet corn processing partner. However, they were able to demonstrate significant yield benefits of the zone-till system with sweet corn compared to conventional tillage. In recent years, the local vegetable processor has come to embrace cover crops and other soil health practices.

In 2001 they bought a true strip-till machine and started experimenting with nitrogen placement. Donn felt they could benefit from placing their nitrogen deeper, and they settled on an 8-inch depth–an approach they have continued for nearly 20 years due to the positive results. Early on, they compared the 8-inch deep nitrogen fertilizer placement with surface and shallow applications, observing much better root growth with the deeper nitrogen. For three years they tested the 8-inch deep nitrogen in combination with strip-till and found yields were consistently better on a variety of farms and different soils. Donn became convinced they were increasing the efficiency of nitrogen application, so they have stuck with the 8-inch deep placement for the last two decades.

They still do a lot of strip-till planting, primarily with grain corn, sweet corn, and snap beans. They have planted soybeans no-till the last several years, and they also no-till drill peas and small grains (oats and rye). Another use of no-till is that they drill several hundred acres of no-till alfalfa annually for a neighboring farmer.

They use a wide variety of cover crops on the farm, although cereal rye is the one used most. This includes growing about 250 acres of cereal rye for seed production–primarily the Danko variety. They

Springtime photo of a biostrip cover crop field shortly after corn was planted green and no-till into the field; the cover crop mix was then spray-terminated. This particular corn field averaged 209 bushels per acre (dry) and needed only 0.76 pounds of purchased nitrogen per bushel of corn yield. Photo credit: Donn Branton.

have also experimented with some hybrid rye for seed production. Hybrid rye yields have been about the same as for the Danko rye (90-100 bushels per acre), but the hybrid rye can be seeded at a significantly lower rate and still produce a comparable yield. Donn does fertilize the cereal rye that is grown for seed production, putting some granular phosphorus in the row with the seed. They apply some nitrogen to the rye to aid seed production, typically about 20 pounds N per acre at early spring green-up, then 50-100 pounds N per acre later in spring, with the final amount based on the vigor of the rye and estimated yield potential. They also scout the rye for insects and diseases and manage accordingly.

Current rotations with cover crops

Donn reports using cover crops in a variety of ways on the farm, and they continue to tweak their cover crop mixes. Currently, some of their common approaches are as follows:

After cereal rye for seed production is harvested, they plant a multiway cover crop blend that is seeded into two alternating strips. On 30-inch centers where corn will be planted the next spring, they plant a mix of cover crops that winter-kill such as radish, oats, and sunflowers. For the row middles, offset by 15 inches, they use a mix of cover crops that are more likely to overwinter, such as rye and hairy vetch. Donn calls this a bio strip-till approach and feels it does a good job of improving the soil ahead of corn planting. The mix of cover crops, including legumes like hairy vetch, also provides some nitrogen and pollinator habitat.

Rather than using a row crop planter, they use the grain drill for this bio strip-till cover crop planting. They direct two drill drop tubes into a Y-connector to get the 15-inch spacings, and have compartments in the drill box that allow the two different seed mixes to be kept separate. That way the cover crop mix that winter-kills can be planted on a spacing of 30 inches apart, with the overwintering type in the row middles offset by 15 inches.

After corn harvest, the Brantons normally drill in cereal rye, then plant soybeans the following spring. The soybeans are no-till seeded into living cereal rye with a planting green approach, and then spray-terminated within 2-3 days after planting the soybeans. They use GMO-free corn and soybeans, so they need to be sure to terminate the rye before the corn and soybeans emerge, but they have their own spray equipment so the spraying can be done in a timely fashion. The soybeans are normally planted before the rye gets too big; typically, it's less than three feet tall when they plant the soybeans.

Depending on the field, after soybean harvest, they either go back to a crop of rye planted for seed harvest or do a cover crop mix before going to vegetables the next year.

After early-harvested small grains they plant a diverse mix of cover crops; they've used up to 16 species at a time. Donn said they constantly adjust seeding mixes, with an eye towards keeping costs in line, in part by being able to cut back on rates of some seeds. Some of the common species they use in a late summer mix are purple top


Photo on left is where cereal rye was seeded through snow on November 11, photo on right of the same field shows rye starting to poke through a later snowfall on January 18 (some of the rye seedlings are circled in red). Photo credit: Donn Branton.

turnip, vetch, fixation clover, Kentucky Pride crimson clover, Frosty berseem clover, medium red clover, Survivor peas, Impact forage collards, Dankon rye, and sugar beets. If it's early enough, he may use some warm season cover crops in the mix, like cowpeas, sorghum-sudangrass, foxtail millet, sunn hemp, oats, soybeans, and/or buckwheat. One example of how they have fine-tuned their seeding rates is cutting radish seeding down to a half-pound per acre as part of a mix.

With early-harvested vegetable crops, they'll use a summer cover crop like sunflowers and/or buckwheat, maybe with radishes, and then plant an overwintering cover crop like cereal rye or winter wheat that fall.

Donn commented that when he uses just cereal rye, such as before soybeans, he plants it pretty late in the fall if he has to, as long as he can still get the drill into the ground. The photos above show rye drilled into a little snow on November 11, and amazingly, that rye started to come up through another snowfall on January 18, as pictured. The Branton farm is in an area where average first frost has historically been in mid-October. Donn likes to use a relatively high seeding rate for rye–around 75 pounds per acre–in order to produce a substantial amount of biomass.

They've also used cover crops in other ways in their rotations. For example, if growing winter wheat for grain, they may frost-seed red clover into the wheat in early spring, letting the clover grow all summer and fall after wheat harvest. The red clover will put on some more growth the following spring prior to corn planting, providing nitrogen fixation that allows cutting back on the nitrogen fertilizer for the corn.

With spring termination of any over-wintering cover crop, they watch the soil moisture and weather forecast. If conditions are dry, they terminate earlier; if conditions are wet, they let the cover crop grow longer. Generally, they terminate the cover crop with glyphosate combined with a residual herbicide applied at the same time. Later, they do one post-emerge application for weed control.

Cover crop seeding method

In earlier years, the Brantons tried flying on some cover crops, in part to interseed them before harvest. Because they experienced inconsistent establishment with aerial interseeding, at this point they try to use a grain drill to plant all their cover crops. A few years ago they invested in a 40-foot-wide Great Plains no-till drill, which they use for their soybeans, peas, small grains, and cover crops. This enables them to pass over all their acres with cover crops. This past year, they seeded a total of about 3,000 acres with the grain drill, not only doing all their own acres but over 1,000 acres for a neighbor. Besides Donn and his son, there is one additional helper on the farm in fall, which usually enables one of them to run the drill as soon as each field is harvested. They've also used the drill to plant alfalfa for neighbors, so it's been a good investment.

Challenges

They've occasionally had issues with slugs–mainly spotty impacts in low wet areas of some fields. If slugs show up, they generally use slug bait, which seems to help. Slugs are not a problem every year, just occasionally. Voles have not really been an issue; they had maybe one field one year in which some corn seedlings were eaten, but they never saw the voles, so they weren't absolutely sure who the culprit was.

When asked about armyworms, Donn said they have occasionally had some armyworms affect oats or wheat planted for grain, but didn't feel the armyworm occurrence was related to cover crop use, since conventional neighbors not using cover crops also had the armyworms.

Benefits

I asked Donn, with his many years of cover crop experience, what he feels are the primary benefits of cover crops on their farm at this point. He rattled off several pluses, such as reduced erosion, better weed suppression (especially winter annuals), and improved soil health. He said when they rent new ground, they see improved water infiltration within just a couple of years of starting to use a cover crop. He told a story about how his neighbors have commented that there isn't water running off the field into their yard the way it used to. On the flip side, they used to see some snow geese in shallow temporary ponds in the fields, and now that the water is soaking in better, they don't get the temporary ponds the snow geese liked!

They have adjusted fertilizer rates. Part of their savings on phosphorus and potassium have come from switching to a precision fertility system with grid testing, although he felt cover crops might be helping a little bit with both. Donn felt the biggest fertilizer benefit had been with nitrogen on corn. Before cover crops, they were applying about 1.25 pounds of nitrogen per bushel of corn yield. Now, due to improved soil health from cover crops, they typically only need about 0.75-0.8 pounds of nitrogen per bushel of corn yield.

Another way Donn reports saving on nitrogen costs is by putting just some of the nitrogen down in spring and waiting to do nitrogen testing to see how much they need at side-dress time; that way, they put on only what nitrogen they need when side-dressing. On some fields, they have found they don't need any side-dress nitrogen, because they are getting enough from the cover crop combined with the spring nitrogen application.

Besides lower nitrogen costs, Donn reported that cover crops have helped with profitability, particularly in terms of yield stability–that the fields with cover crops just seem to more consistently have good yields.

When asked why they keep using cover crops on the farm, Donn said it's a mix of several benefits. If they rent a new piece of ground, they want to treat it like their own, so they use cover crops, and they've seen enough benefits to keep doing it. Another benefit after using cover crops over time has been improved soil tilth: it's easier to plant into the soil, and seems looser even though they don't do any full-width tillage.

For farmers not yet using cover crops, Donn said to consider the wide range of agronomic benefits and biological benefits, including better rainfall infiltration, recycling nutrients, stopping wind and water erosion, and keeping something green on the soil. He finished by saying, "It's important to feed the soil, feed the microbes, and use cover crops to harvest sunlight, building soil nutrition."

John Burk (Michigan)

Photo courtesy of John Burk

John Burk farms 4,300 acres in central Michigan. The majority of his acres are in corn and soybeans, but he also averages about 500 acres of wheat, 400 acres of dry beans (usually navy beans) and grows some sugar beets. With all these crops to deal with, he does not have livestock.

He and his father got started with cover crops in 1999 because they were having a problem with nematodes in sugar beets, and had heard that using oilseed radish as a cover crop after winter wheat and before the sugar beets could help reduce the nematode problem. In that process, they observed that growing a cover crop boosted earthworm numbers and loosened the soil.

The farm generally has heavy clay loam soils, but in some fields it is more of a sandy loam, especially close to Saginaw Bay. John has fields spread out over about a 35-mile area, so there is a range of soil types.

Growing radishes after wheat was their main cover crop approach for about four years, but they started feeling like they needed something else to help deal with soil compaction caused by sugar beets, so they tried growing cereal rye after beets. They broadcast the rye seed and lightly tilled it in, liked the results, and have continued to use that approach over the years.

Then someone suggested radishes would do better with some additional nitrogen, so John started adding Austrian winter peas to the radish seed. In his area, he's found that sometimes the peas winter-kill after having grown only 5-6 inches in the fall, but if the peas do overwinter, they can gain two feet of growth in the spring, which really mellows the ground. He continues to use a mix of radishes and peas, and now broadcasts them with potash fertilizer in the fall, followed by disking to ensure some seed-to-soil contact.

If the peas get too big and ropey (viney) in the spring, he may use a turbo till or speed till disk to chop them up; he's tried a few tillage approaches. The peas provide more nitrogen when they overwinter, in which case John may adjust nitrogen fertilizer, but it just depends on the year.

When he uses rye after beets, he'll typically go to soybeans next, or occasionally to dry beans. After soybean harvest, he will often do winter wheat planting in the fall.

Where corn is in the rotation, it sometimes comes after soybeans; a cereal cover crop is then used after the soybean harvest. He uses cereal rye the most often, but sometimes he uses winter barley or spring barley.

After sugar beet harvest, he grows spring barley, although he's grown cereal rye instead at times. He likes the extra fall growth of the spring barley; sometimes it will head out before being winter-killed. He feels the barley leaves the ground very mellow and doesn't have as big of root clumps as some of the winter cereals, which primes the ground for planting to seed corn or, sometimes, back to beets.

If it's too late to use spring barley, which for him is a cutoff of around September 20, he switches to winter barley through October

10, at which point he starts using cereal rye for the late-fall plantings.

He has noticed deer eating the radishes and peas after the first snow, but they seem to leave the cover crops alone prior to this time of year.

John has occasionally planted some no-till soybeans, but in his area, he and most farmers till the ground in the spring to warm up the soil. He has tried a little no-till corn seeded into a rye cover crop on sandy fields, and feels the rye helps the corn in these light soils, providing a beneficial mulch over the field and retaining soil moisture.

Unlike many farmers who terminate all their overwintering cover crops with herbicides, John sometimes uses only tillage to terminate the cover crop. His rule of thumb is that if the cover crop is under knee-high, he'll till it to terminate it, then plant his cash crop. If the cover crop is taller than knee-high, he'll spray it, then till and plant.

He uses a variety of planters, depending on the cash crop. For corn and sugar beets, his set-up is a John Deere 1795, using a single fluted no-till coulter in front of each row unit. He also uses a Keeton seed firmer to make sure the seed travels all the way down into the furrow. He uses standard round, rubber closing wheels.

For soybeans and wheat, he runs a big air seeder, drilling into narrow rows. The wheat is normally no-till planted unless there are ruts in the field he needs to address through tillage.

Cover crop seeding methods

John has used a variety of methods for cover crop seeding. Most commonly, the seed is fall broadcast and then lightly tilled for incorporation. For a cover crop like rye, he might do heavier tillage after broadcasting if it's part of his rotation; for example, after soybeans he will spread the rye and chisel the ground.

In recent years, John has tried to plant at least 50% of his fields to cover crops every year–however many acres he has time to plant.

Benefits of cover crops

John feels the cover crops are definitely helping with weed control. With Austrian winter peas, he feels he additionally gets the added benefit of more nitrogen. Since he does a split nitrogen application on corn, with 30% before planting and 70% side-dress, he can adjust the nitrogen fertilizer rate at side-dress time for what is needed then.

Another cover crop benefit has been mellower ground. If he does run a subsoiler, he has noticed it's easier to pull through ground that has been cover cropped, and the subsoiler doesn't throw up big chunks of soil like it used to.

He has gained about 1.5% soil organic matter since 1999 when his fields were generally 1%-2% organic matter–a big soil health change. Note that this is even with some tillage, though less than they used to do. The rainfall infiltration rate is also much better; they don't have nearly as many ponds in the fields after a big rain as they used to. He feels their soil structure is definitely better following cover crop use.

As far as profitability goes, John feels the main advantage is having better yields. He feels cover crops are helping his soybeans yield about 10 bushels more per acre than before, and his corn yields are about 20 bushels more per acre than the county average due to overall management, including cover crops. Sugar beets are also yielding better; recently he achieved 43 tons per acre, whereas he used to have yields in the mid-20s or low 30s. Wheat yields have stayed more stagnant at around 80 bushels per acre.

When asked what he would tell farmers in his area who are considering cover crops, John said to look at cover crops as a way to increase soil health. He commented that simply adding fertilizer doesn't keep the soil's biological activity going like cover crops do, and that you need to keep living material (roots) in the soil. It's all the things you can't see–the microbes–that are important for the soil.

He suggests starting small when trying cover crops–"Don't plant 1,000 acres of rye [the] first time out"–and start out with one or two fields. He observed that first-time users of cover crops could start by trying a winterkill cover crop like radishes, or maybe something less aggressive than cereal rye like winter barley or winter wheat. However, he feels that eventually planting rye is better for the soil. Overall, he's glad to be using cover crops and receiving the benefits.

Dan DeSutter (Indiana)

Photo courtesy of Dan DeSutter

Dan DeSutter operates a 5,000-acre family farm in west central Indiana that for many years was focused on corn and soybeans. Over the last decade, he has gradually added a variety of other cash crops and integrated beef cattle into the operation. He first added small grains and then some alfalfa to the rotation to incorporate more diversity. Now, with the opportunity for cattle grazing present, he is growing a variety of annual grazing forages, usually as mixtures. They previously had a modest number of stocker grass-fed beef cattle on grass pasture, but have now converted to cover crop grazing with a cow-calf system, using diverse perennial pasture mixes when no cover crops are available to graze. No-till and cover crops are used on 100% of the non-pastured fields.

Dan periodically hosts visiting agronomy classes from nearby Purdue University.

Dan got his start farming with his father. While his father is now retired, Dan has three sons in their 20s who have all joined the farming operation in the last few years. Dan's motivations to diversify the enterprises on his farm are to achieve better soil health and also to create long-term farming opportunities for his three sons. His hope for the land is to restore the soil organic matter to near the level it used to be at when farming began on the prairie soils in his area. By attaining that amount of organic matter, Dan believes the farm will be more resilient to both weather and economic challenges and provide a more stable operating base for his sons in the future.

Dan made a major decision to transition the farm to organic starting in 2017, feeling that the higher prices would create more economic opportunity for his sons and fit better with the way he wanted to farm. At the time of writing, most fields have completed the three-year organic transition process and are now certified; others are in transition.

The farm went no-till in 1991, and Dan began growing cover crops in the late 1990s, initially as a favor to a Purdue professor who wanted to collect some data on cover crops. He originally wasn't too excited about trying cover crops, but Dan says his aha moment came when he was digging a hole to repair a drainage tile line in one of his fields on an early spring day. He had planted annual ryegrass the previous fall that was not particularly tall–maybe 6 inches–so he was surprised to find ryegrass roots 4 feet deep where he was digging for the tile. That got him thinking about the root growth of cover crops and initiated a journey of learning more about what cover crops can do for the soil.

During a class, Dan illustrates the value of using a shovel to see what's happening in the soil, in this case under a diversified mix of radishes, crimson clover, and rye.

After primarily using annual ryegrass for several years, he started experimenting with other cover crops, trying oats, radishes, cereal rye, and crimson clover, among other species. His system has evolved to the point where he customizes the cover crops for each field based on the rotation and his goals for the cover crops in that field. He often custom-blends a mix of cover crops, with an overall goal of achieving as much diversity in his cover crop mix as he can afford and is appropriate to the time of year the mix is planted.

For many years, Dan farmed just corn and soybeans in a no-till system with cover crops. As he increasingly valued the benefits of plant diversity, he introduced additional cash crops to his field rotations. He now has a highly diverse rotation, both in the number of cash crops rotated and the diversity of the cover crop mixes used at every opportunity in the rotation. He feels winter cereals are a particularly valuable part of the overall rotation because they allow him to incorporate a cover crop cocktail of 8-12 species after early harvest, significantly boosting overall diversity.

Dan believes you can't have healthy soils without plants, so his goal is to have something growing at all times on every acre. To further improve soil health and overall farm profitability, he made the decision about four years ago to start setting up a comprehensive beef cattle grazing system. This required several changes, starting with trading some fields with other owners to have as much land near his home place as possible and get rid of fields that were too far away to graze easily. Next, he and his sons worked diligently to equip their fields for cattle, installing several miles of perimeter fencing and extensive buried water lines.

As far as the cattle themselves went, Dan and sons switched from having some stocker cows in dry lots to buying 180 mother cows and setting up intensive rotational grazing for the cow-calf system. The cows graze on cover crops as well as perennial plants in some fields. The beef is then marketed as grass-fed, as it is raised and finished on pasture.

Considering the large number of cover crop acres he had to seed, Dan invested in a 40-foot wide grain drill to seed most of his cover crop acres and allow him to plant quickly. He has also used a broadcast seeder integrated with a vertical tillage unit to seed cover crops. However, Dan prefers the seed-soil contact a drill gives him for establishing cover crops. The main reason he does a little vertical tillage on a few fields is as a follow-up in places where a contractor brings in hog manure and Dan needs to level the soil after manure spreading. The manure helps with his organic nitrogen needs as well as building soil organic matter.

In the past, Dan has used herbicides for termination of cover crops, but recently he has been shifting to using a custom-made 60-foot roller crimper, especially on all his soybeans planted green into cereal rye. Initially, he would roll the rye at the pollination stage; now he plants the soybeans while the rye is still in the boot stage if the timing works, then rolls the rye once the beans have emerged and are at the V2 growth stage. He likes that approach since it allows him to plant soybeans earlier. Dan said that with his transition to organic, he's considering using light vertical tillage to help with termination of certain cover crops, though he wants to minimize soil disturbance. However, he commented that his priority is keeping living roots in the soil, even more than avoiding any type of tillage; he feels that to build and maintain soil health, he can't get by without having plants in the soil year-round.

In a rotation before corn, Dan tries to avoid using cereal rye because of various potential issues, including army worms that they have seen regularly on the farm. Instead, he's used a variety of approaches before corn. In some cases, he has planted earlier maturity beans the previous year, then planted a oat-radish-clover-hairy vetch cover crop mix, sometimes adding a little barley as well. His favorite approach before corn has been to grow winter wheat and then plant a diverse cocktail after wheat harvest. Now that he is doing more grazing of cover crops, he also has the opportunity to graze this cocktail.

Dan has also changed the way he does seed selection. About seven years ago, he started using GMO-free corn and soybean seed that was additionally free of insecticide and fungicide seed coatings. As a result of using corn seed that is free of seed coating treatments, he has adjusted his corn planting date to be a little later. His rule of thumb is to wait for corn planting until May 1 or later, also waiting until the soil temperature has reached 62°F or more at a depth of four inches under sod. He also looks at the projected temperature forecast for the week after his potential planting date. In some cases, he plants corn after alfalfa, and delays the planting date for the corn in order to allow the alfalfa to produce more spring nitrogen.

Another adjustment he has made to his operation in relation to cover crop use is to grow early-maturing corn, which gives him more time to drill cover crops after corn harvest. Planting the cereal rye cover crop before October 1 greatly enhances tillering and biomass, which is the key to achieving adequate weed control in no-till organic soybeans.

Looking ahead, Dan is hoping to identify a mix of covers that he can grow between his corn rows during the summer season, helping with weed suppression and biodiversity. If he could find a mix of perennials that would work and not have to be reseeded, that would be ideal to him. After his initial experimentation with in-season covers between corn rows, he has wondered if those covers help increase soil moisture in the form of providing extra surface area for dew to collect on and then drip into the soil.

Dan has observed that his cover crops provide advantages in both wet and dry years. For example, in the drought of 2012, he had some fields with yields that were not much reduced compared to in wetter years, while his conventional neighbor saw some significant yield losses. Dan attributed that to better soil moisture retention in his long-term no-till and cover cropped fields. He also feels that cover crop residue helps minimize moisture loss and keep soil cooler.

In wet springs, the covers can be managed to help dry out the soil by letting them grow longer, which was helpful in the wet spring of 2019. However, proper termination timing is key to working with cover crops in both wet and dry springs.

In terms of profitability impacts of cover crops, Dan stated that you can't have good soil health without living plants year-round, and improved soil health is, for him, an integral part of profitability. Before transitioning to organic, improved soil health from cover crops and no-till enabled him to use less fertilizer and other inputs and have more reliable production, resulting in a positive impact on profitability. The better soil health and increased profitability have not been at the expense of yields. In fact, in 2018 his crop insurance agent told him that his farm had the highest average production history (APH) yields of all the farms serviced by that agent in the region. Dan did comment that with his move to organic, his focus will be squarely on profitability rather than maximum yields, and he does expect corn yields to be somewhat lower than in the past, but higher prices and lower costs will more than offset the yield reduction. He is hoping that his organic soybean yields will be close to what he saw under his previous no-till and cover crop system.

Looking ahead, Dan is very motivated to keep using cover crops, because he has come to understand that healthy, functional soil requires living plant roots at all times. He shared that he hopes more farmers will come to recognize that the lack of living plants on conventionally farmed fields creates the need for a lot of expensive purchased inputs. He pointed out that farmers wanting independence from such high input costs should be thinking about how to make their soils more functional through increased use of living roots year-round, and other soil health practices.

Jimmy and Ginger Emmons (Oklahoma)

Jimmy and Ginger Emmons; photo courtesy of the Emmonses

After hearing Ohio farmer Dave Brandt talk about cover crops in 2010, Jimmy Emmons's interest in them was sparked. He heard Dave talk about how his cash crops had responded well to cover crops, nutrient management was improved, and the cover crops built soil health. Jimmy came away convinced they needed to try them on their farm, even though he was in a very different region of the country. Jimmy and his wife Ginger farm in western Oklahoma, an area with about half the annual rainfall of where Dave Brandt farms.

Jimmy became interested in conservation early on in his farming career, trying his first no-till fields in 1995 at a time when his parents were still doing conventional tillage. It took a while to figure out how best to manage no-till in his area, but by 2010 every field they owned was no-till. The next step was trying cover crops.

At first, they planted a warm season mix of about six species, including sorghum, millet, and cowpeas. This was planted after winter wheat harvest in mid-summer. Over time, they experimented with various options, and now try to plant every field to cover crops, either after winter cereal harvest in mid-summer or after cash crops like sorghum are harvested in fall.

The Emmonses currently row crop about 1,400 acres and also utilize about 5,500 acres of native range, moving cattle between rangeland and cover crop fields for grazing based on season and forage availability. They typically have about 200-250 head of cattle at any one time. They've become increasingly diversified with row crops, trying to have at least a four-year rotation on each field. Common cash crops are sorghum (milo), soybeans or cowpeas (or occasionally mung beans), sesame or sunflowers, and a winter cereal. While winter wheat remains their primary winter cereal, they have grown some triticale, winter barley and cereal rye for seed harvest. Jimmy noted that they've had to stop growing corn because of problems with feral hogs in their area.

After the winter cereals are harvested in mid-summer, they always drill in a warm season mix of about 15 cover crop species. A typical summer mix primarily includes warm season species, such as a couple of types of sorghum or sorghum-sudan, three species of millet (proso, foxtail, pearl millet), sunn hemp, and cowpeas. They also include a few cool season species in the summer mix, such as collards, sweet clover, and red clover. They stagger the summer cover crop plantings a bit depending on rainfall to try to provide a variety of grazing options going into fall.

After harvest of summer cash crops in the fall, they also plant a diverse cover crop mix, but use only cool season species at that time of the year. Typical cool season covers they drill in the fall include triticale, winter barley, winter wheat, forage radish, forage turnip, hairy vetch, collards, and red clover. If they are seeding the cover crops late in the fall, they simplify the mix to include only winter cereals, since the cereals are more tolerant of late planting.

Jimmy said they've found that it really pays to use a grain drill for cover crop seeding in their area, as they can't count on having rainfall to sprout broadcasted cover crop seed.

Grazing cover crops

For the Emmonses, one of the most valuable aspects of cover crops is their ability to provide extra forage. Jimmy commented that he has calculated they are making an average extra net profit of $170-$180 per acre from grazing the cover crops. For grazing the summer cover crop mix, they typically put out cow-calf pairs into the cover crop fields in August. After letting them graze for 10-14 days, they wean the calves by moving their mothers onto other forage, usually native range, and leaving the calves in the cover crop fields where they have high quality forage to continue putting on weight. The calves contin-

Cattle grazing cover crops on the Emmons farm; photo courtesy of Jimmy Emmons ue grazing on cover crop forage during September and October, and are then moved onto cool season cover crop fields in late fall. After a couple of months of grazing cool season cover crops, the weanlings are at their target weight of 800-900 pounds, and will go to market in December or January.

While grazing cover crops in fall, the Emmonses typically move the cattle between grazing paddocks every two to three days to optimize forage use. After weanlings are sold in December and January and they have only the older cows left to graze, they reduce the frequency of moves to once a week, giving them a little more flexibility to travel to winter farmer meetings and do other activities at that time of year.

With the cool season covers planted in fall, they do a final round of grazing in early spring once the winter annual cover crops have grown a sufficient amount.

Cover crop termination

While the warm season cover crops they plant in summer will all be killed by winter weather, they do have a variety of over-wintering cool season cover crops they normally terminate with spring herbicides. Jimmy said he's been interested in using a roller crimper as a termination tool; an incentive program they are doing with General Mills has encouraged him to explore that option.

They base their termination approach on soil moisture, terminating early in the spring if conditions are dry. If they have a spring with enough soil moisture, they keep the cover crop growing longer and plant green into the still-living cover crop. He prefers that approach if they have enough rainfall to do it.

Fertility changes

Jimmy shared that they have been able to cut back quite a bit on crop fertilizers and have learned to focus more on maximum profit than maximum yield. The legume cover crops and cash crops in their system have contributed nitrogen. The overall combination of cover crops, no-till, and diversified rotation has boosted soil health and soil organic matter, reducing their fertilizer needs. Grazing of livestock on their crop fields has also contributed to fertility and stimulated soil biology. To further enhance the soil biology, they've experimented with some compost tea applications, such as applying the liquid compost tea as an in-furrow seeding time application.

By emphasizing soil health management over several years, Jimmy said they've been able to cut back their fertilizer program by over half on all their crop fields. For cash crops like sorghum, sunflowers, or sesame, they can often get by with a modest 20 pounds of nitrogen fertilizer per acre due to their other fertility enhancement management methods.

Soil and economic impacts

When asked about soil improvements from cover crops and no-till, the first thing that came to mind for Jimmy was the big positive impact cover crops had on rainfall infiltration, which is critical in his low-rainfall area of western Oklahoma. In fields that had been farmed conventionally, Jimmy said rainfall infiltration was only about a half-inch per hour, so heavy rains resulted in a lot of the rain running off the fields. Now, after several years of no-till and cover cropping, they see up to 8-10 inches of rainfall infiltration per hour, allowing every drop of rain to soak into the soil. The improved soil organic matter and soil aggregate structure has also increased the soil's inherent water holding capacity, creating more of a moisture reservoir for dry periods.

Jimmy observed that cover crops have helped significantly both in excessively wet periods and prolonged dry periods, which has really helped them stay in business. He commented that cover crops have made their operation resilient to extreme whiplash weather. During periods of drought, they have more soil moisture than conventional fields do, and when they do experience a rainstorm downburst, their fields capture every drop of rain.

He credits the use of cover crops and no-till, including grazing cover crops, with allowing them to improve their farm finances significantly and get to the point where they haven't needed an annual operating loan from a bank. The extra forage available from cover crop grazing has also taken pressure off their native rangeland for grazing, especially in the summer-to-winter period.

Asked about what message he would give to farmers who haven't yet tried covers, Jimmy said, "Never say never. There are so many places to go learn about covers–conferences, books, farmer networks, and social media." He suggested farmers take time to learn more about the soil and water cycle. For him, that learning process made him realize that the traditional system of using periodic fallow to conserve moisture was not working and they needed a different approach.

Ultimately, Jimmy is really happy they converted to cover crops and no-till, and feels these management techniques have allowed them to stay in business and be profitable. He ended by stressing their desire to leave the land better than they found it, something he believes they are doing successfully with their focus on soil health.

Ray and Chris Gaesser (Iowa)

Chris (left) and Ray (right) Gaesser on their Iowa farm in a field planted with cereal rye. Photo courtesy of the Iowa Soybean Association.

In May of 2010, Ray Gaesser and his son Chris watched with concern as an intense storm dumped over four inches of rain in less than an hour on their corn and soybean farm in southwest Iowa. Fields that were terraced and had been no-tilled for over 20 years still had damaging soil erosion, with some terraces breaking through from the heavy downpour. All their previous efforts at erosion control–the grassed waterways, terraces and no-till–just weren't doing enough to protect their land and keep valuable topsoil from washing away. They started to think, what else can we do to protect our land? For them, the answer was to try cover crops, so they planted 200 acres of cereal rye that fall.

Pleased with the initial results from that first cover crop experience in 2010, they kept doubling the area of cover crops they planted for the next several years, concentrating at first on their most erosive hill ground. They were grateful for that cover crop protection of their soil, because for the next six years, every year they had at least one

At top: The Gaesser's John Deere R4030 high-clearance sprayer unit modified with a New Leader spreader that can be used for granular fertilizer and/or cover crop seed; in this photo it is being used to spread urea fertilizer into corn. At bottom: Photo showing timing of cereal rye broadcast seeding with a JD R4030 in relation to soybean leaf yellowing. Photos courtesy of Ray Gaesser.

intense rainfall event of four or more inches of rain in an hour. By 2015, they were up to 2,500 acres of cover crops planted. From that point on, they have planted as many acres of cover crops as time permits each fall. In the fall of 2021, they managed to plant 3,400 acres of their 5,000 acres to cover crops.

Approach to seeding cover crops

At first, all their cover crops were seeded with a grain drill. The grain drill was a reliable way to plant the cover crops and worked well with the cereal rye they were mainly using. However, the extensive cover crop planting was putting quite a bit of wear on their grain drill and they wanted to be able to plant more acres more quickly, so they started evaluating other options. They ended up switching most cover crop seeding to use of a John Deere R4030 high-clearance machine that they could spray chemicals with, switching out the spray tank to use a New Leader spreader box for both cover crop seed in fall and granular fertilizer for side-dress applications on corn in early summer–usually urea or ammonium sulfate applied at the V6 stage.

The broadcast spreader has allowed them to cover more ground for cover crop seeding, up to 100 acres per hour. It has also allowed them to change the timing of seeding in soybean fields. Starting in the fall of 2019, instead of drilling after soybean harvest, they now broadcast seed into the soybeans before harvest, following the same sprayer tracks used for herbicide spraying earlier in the season, on 100-foot intervals. The broadcast spreader will throw the cereal rye almost 100 feet wide, but they have to be careful about not doing it on really windy days because the broadcast pattern can be too affected by the wind.

Ray said timing of the broadcast spreading into standing soybeans is very important. They try to go out when the soybean leaves are just turning yellow and the first leaves are starting to fall. If they go any earlier, the still-green soybeans can shade out the rye, preventing it from becoming established. And if they go too late, when there is a thick layer of soybean leaves on the ground, that can leave the rye seed sitting on top of soybean leaves instead of in contact with the soil; adequate seed-to-soil contact is critical for germination and establishment. Ray did comment that a good rainfall makes everything simpler, because it will wash the rye seeds into better contact with the soil. If rain is forecast, they can seed even if there is already a moderate amount of soybean leaves down.

Doing a substantial amount of cover crop seeding prior to soybean harvest prevents time conflicts during the busiest stretch of fall harvesting and gives the cover crop more time to grow, which is good for the soil and creates more grazing opportunities.

Following corn, they use a different approach: they wait until right after the corn is harvested, then try to seed rye immediately within a day or two of corn harvest, or even the same day. Ray commented that they have found doing the rye broadcasting while the corn residue is still loose and fluffy on the ground allows the rye seed to pass down through the corn residue and into contact with the soil better than if they wait until after the corn residue has started to pack down.

Most of their cover crop acres are cereal rye. However, they do plant a diverse cocktail mix of cover crops on fields where the rye was grown for harvest. Each year, they devote some land to growing their own cereal rye cover crop seed, and after harvesting that rye in early August, they drill in a mix of warm season and cool season cover crops, such as sunflowers millet, canola, mustard, and other Brassicas, and various legumes. When they can, they work with neighbors that have cattle to graze that cover crop mix.

They have also collaborated with neighbors on grazing some of their cereal rye cover crop. The neighbors will bring in cattle for about 30 days of grazing, using portable electric fencing and portable water supply. This provides extra income, and Ray feels that the grazing builds soil health and has gotten some of his neighbors interested in cover cropping. The rental rate for grazing the cover crop ground is based on the number of days of grazing and the number of cattle per acre.

When they are growing cereal rye for their own seed production, they drill it at the rate of 80 pounds per acre using a named variety. They buy fresh certified or registered seed every three years or so,

At top: A diverse mix of cover crops photographed on August 30 after planting on August 2, following harvest of a cereal rye field for seed production. At bottom: A test plot of soybeans planted into Kentucky Bluegrass. Photo courtesy of Ray Gaesser.

otherwise using their own farm-produced rye for additional cover crop seed production.

For all their other acres of cereal rye cover crop seeding, they broadcast at a more moderate rate of about 50-55 pounds per acre. Ray said they value the seed they grow at about $10 a bushel, and since the seeding rate is about a bushel per acre, they have an affordable seed cost of $9-$10 per acre (a standard bushel of cereal rye is considered to be 56 pounds). Their cost of seeding is about $5-$6 per acre using their broadcast spreader, including cost of equipment, fuel, and labor. Thus, their total cost of seeding is currently $14-$16 per acre.

Ray said they've gotten better at producing cereal rye seed for their own use, and now typically get a yield of 50-60 bushels per acre. Given the low input costs for growing the rye for seed, it is a profitable part of their operation. He pointed out that cereal rye seed production is usually done on their poorer soils, which can be improved by using the rye production, followed by a diverse cover crop cocktail and often some grazing.

Ray and Chris are continuously trying to learn and innovate, so they are exploring additional cover crops and rotation options. For example, they have worked with Corteva researchers to try experimental plantings of yellow peas broadcast into soybeans in the fall. The peas are harvested the next August and a diverse mix of cover crops, including oats and sorghum, is planted afterwards.

They've also participated in a joint project with Iowa State University and Corteva researchers the last couple of years trying to establish Kentucky bluegrass as a permanent cover crop in trial plots. The bluegrass is seeded in the fall. Ray said they've found it easy to no-till soybeans into the Kentucky bluegrass the next spring; they apply some Liberty herbicide to the bluegrass before corn or soybean seeding to set the bluegrass back a bit (the herbicide temporarily browns the bluegrass for a couple of weeks while the corn or soybeans start to grow). Planting corn into the bluegrass has been a bit more challenging than with soybeans. Ray feels they may need to clear a narrow planting strip with trash-clearers or equivalent devices on the planter when doing future planting of corn into Kentucky bluegrass. In the couple of years of small trials to date, the bluegrass has survived beneath the growing soybeans pretty well, but it's been more challenging to keep the bluegrass alive under corn and to figure out the best herbicide regimen. However, they continue to experiment!

Termination and cash crop planting

The Gaessers used to terminate their rye before soybean planting, but starting in 2019, they switched to planting most soybeans into still-living rye (planting green). They usually spray-terminate the rye within a day or two of soybean planting, or sometimes immediately before, depending on weather conditions.

This change to planting green was partly precipitated by weather conditions, because they had a very wet spring in 2019 and were not able to terminate their rye as early as usual; the plus side of this was that the rye cover crop fields were able to be planted sooner than the ones without cover crops.

Ideally, they like to plant the soybeans when the cereal rye is about 2-2.5 feet tall; they prefer not to let the rye head-out before planting. Ray said being able to use the rye as a soil moisture management tool in spring is a big reason for planting green, as it allows them to dry wet fields out a little and plant earlier compared to fields with no rye. He also likes maximizing the cover crop benefits by letting the rye grow a little longer, and said the bigger rye does a better job of holding corn residue in place when a big spring rain comes, rather than the residue washing away and piling up in big clumps downslope.

They are not yet comfortable planting green with corn, so they terminate the rye when it is about 6-12 inches tall and then plant the corn about 10 days later. Ray felt that if they were going to start planting corn into still-living rye, they would need to change their planter setup so they could apply nitrogen starter fertilizer.

Their overall corn nitrogen program, whether they use cereal rye or not, is to apply 120 units of nitrogen in late fall as anhydrous and then do a side-dress application of granular urea or ammonium sulfate nitrogen fertilizer into the corn when it is at about the V6 stage. They do the fertilizer application themselves and base the side-dress rate on charts that take into account rainfall, soil factors, and yield goal.

To plant soybeans, they use a John Deere air drill and 10-inch rows. Corn is planted on 30-inch rows with a no-till planter that is set up with no-till coulters, but not trash-cleaners. For closing wheels, they've found standard smooth wheels work well. They use a steel closing wheel on one side of the furrow paired with a rubber closing wheel on the other side.

When asked about any changes to their fertilizer or chemical program, Ray said they've pretty much stuck with their standard fertilizer rates, though they continue to evaluate that. However, they have been able to use less herbicide at times. If they produce a large-enough amount of rye biomass, they are often able to get by with one post-emerge herbicide spray application instead of the two post-emerge sprays they would more typically do.

Ray also commented that cereal rye has helped significantly with lambsquarter and waterhemp control, based on rye's allelopathic ability to help suppress small-seeded broadleaf weeds. Another weed control impact is that marestail, which is a general problem in the region, has nearly disappeared on their farm, due to rye's potent ability to prevent it from growing.

Soil health impacts

When asked about soil health impacts from cover crops, Ray shared that NRCS staff had come out to his farm the previous year for some staff trainings and did soil tests while there. He was particularly interested to see the results of the water infiltration tests on his fields. A field by his house that had been cover cropped for 10 consecutive years and underwent 30 years of no-till was tested for water infiltration in April after a dry spell. That field soaked in an inch of water in 2-3 seconds; when a second inch was added, it infiltrated in 30 seconds–still very quick. The NRCS staff then repeated the test on a field about a half-mile away that Ray had recently started renting, which had been conventionally farmed up to that point. For that field, the first inch took much longer at 7-8 minutes (compared to 2-3 seconds on the first field).

The rainfall infiltration test was repeated in late May on a second NRCS staff visit when the corn was about 6-8 inches tall. Unlike the previous occasion when the ground was dry, the soil was wet because it had rained 5.7 inches the previous week. Despite all the recent rain, the long-term cover crop and no-till field by Ray's house still soaked up an inch of water in less than two minutes. When they repeated the infiltration test at the rented field that had been conventionally farmed, they tried the one-inch infiltration test for 15 minutes and then gave up, because the inch of water in the column had only partially soaked in.

NRCS staff also demonstrated that soil aggregate structure was much better on the long-term cover crop no-till field by using a slake test (putting a clod of soil from each field in a large tube of water). The soil from the field that was rented and previously conventionally managed had poor soil structure, with the soil clods breaking apart quickly in the water column, indicating that the field would be highly prone to erosion.

Ray commented regarding those two fields that when it got dry later that summer, the field by his house stayed green and healthy while the rented field a half-mile away was showing moisture stress, likely because some of the rain had run off of that field instead of soaking in.

Other observations by Ray from cover cropping are that his fields no longer have water ponding up in low areas, reflecting better drainage. Very importantly, he and Chris have been able to plant the cover-cropped no-till fields earlier than neighboring fields that have been conventionally tilled and have no cover crops.

In fields where the Gaessers have had long-term cover crops and done no-till, their yields are noticeably better than in fields they've recently rented that have been conventionally farmed.

Ray also mentioned that when contractors come to work on their waterways, terraces, or tile lines, the contractors routinely comment on how surprised they are by the lack of erosion on the farm and how easy the soil is to work with compared to conventionally managed fields on other farms.

I asked Ray what motivates them to keep using cover crops. His response: “First thing is, it’s a long-term investment in the future, it’s a wise and morally right thing to do, it keeps the soil where it belongs, and keeps the water clean. Second, we’re more financially resilient with cover crops and no-till.”

When asked what he would tell farmers still considering whether to use cover crops, Ray said to start small and give yourself a chance to learn how to do it. Also, recognize that this is about protecting your investment (Chris really stresses that, too), and there are lots of good reasons to use cover crops. Understand that it can take time to see results, but they will come!

Trey Hill, Harborview Farms (Maryland)

Trey (right) with his father Herman(left). Photo courtesy of Harborview Farms.

As reflected in the name of their operation, Harborview Farms, Trey Hill and his family live and farm very close to the Chesapeake Bay, America's largest estuary and an important body of water for fishing, crabs, shipping, and recreation. He and his father first got started with cover crops in 1998, following efforts by the Maryland state government to start doing a better job of protecting the water quality of the Chesapeake Bay watershed. Trey farms in an area that consists largely of flat fields of corn and soybeans, not too dissimilar in appearance from the grain fields of the Midwest, except for the nearby seagulls and smell of saltwater. Trey's initial interest in cover crops was motivated by payments offered for planting them, but he quickly came to see the inherent value of cover crops.

Over the nearly 25 years that have passed since they started using cover crops, Trey and his father have made a number of changes to their operation as they've gained a better appreciation for soil health management. Trey has experimented with a variety of cover crops, reduced tillage on his farm, and made use of small grains (primarily wheat) where feasible. Initially, his tillage system consisted of using a chisel plow on at least half his acres and frequently deep-ripping the soil. Spring planting preparation involved disking and running a field cultivator. He wanted to move towards no-till, but was seeing some decreases in yields when making the switch to no-till on a field. Then he found that using a cover crop first and then making the switch to no-till could alleviate much of that yield depression and make the transition to no-till easier.

He now plants cover crops on all 13,000 of his row crop acres and uses no-till on most fields. His first cover crop was winter wheat, but over the years, he's used crimson clover and hairy vetch as legumes; radishes and rapeseed from the Brassica group; and barley, cereal rye, and winter wheat as cereal covers. Since he doesn't have livestock, the grazing value of the cover crop doesn't factor in, but Trey does think about feeding the biology of the soil organisms and the value of having a variety of cover crops.

Planting soybeans into a mix of rapeseed, clover and rye with a planting green approach (in this part of the field the rapeseed is the predominant species visible in the photo). The cover crop will soon be spray terminated. Photo courtesy of Harborview Farms.

When planting cover crops, his preference is to drill them in for optimal seed-to-soil contact, which he does on about 75% of his acreage. Some are broadcast-overseeded into standing corn and soybeans to give them an earlier start, and to get some of the cover crop seeding out of the way earlier.

Over the years, Trey has moved from early termination of cover crops to allowing them to grow longer, and now tries to always plant green with his cash crops into still-living cover crops. For soybeans planted into living cereal rye, he sometimes uses a roller crimper for termination, but most of his cover crops are spray-terminated, usually soon after the corn and soybean planting. He has experimented with late termination, waiting as many as four weeks after cash crop planting to terminate a cover crop in order to gain some extra biomass. He is particularly likely to let the cover crop continue growing if the soil is cold and wet when planting his corn or soybeans.

While he has kept his nitrogen fertilizer rates the same as before he had cover crops in the system, he has adjusted the method of nitrogen application, particularly for high-biomass cover crops before corn. If there is quite a bit of cover crop growth, he applies extra starter nitrogen at corn planting time using a 2x2 applicator on the corn planter, which places nitrogen two inches to the side and two inches below the depth of the seed placement. He then applies 30-40 pounds of nitrogen as a sidedress application in the same equipment pass made for applying herbicide to the field, while the corn is emerging or still small. He usually does a later in-season sidedress application of 100 pounds of nitrogen per acre, too. He no longer does any fall nitrogen application, and believes timing the majority of nitrogen application to be when the corn is actively growing is the best strategy.

Trey indicated that he has been able to cut back on some herbicide costs. For example, he used to apply 6 pints of Lexar herbicide per acre, and now when he uses it he can get by with 4 pints per acre. Where he used to rely on residual herbicides with soybeans, he is now getting by with just a post-emerge application in many cases.

Trey shared the story of how the cover crops on one of his fields had excellent growth and achieved five tons of biomass per acre, leading to excellent weed control. In contrast, there was a check strip in that field that was tilled, and it was absolutely loaded with weeds.

Another benefit of cover crops has been the ability to plant earlier in many cases. He used to plant corn starting in mid-April and now finds that he can often start planting corn at the end of March, ahead of the corn planting in neighboring fields. Trey attributes this earlier start to the cover crops helping cold, wet soils reach planting condition faster, along with better soil structure and drainage in the cover-cropped fields.

Slugs have been an occasional problem with his cover crops, so Trey and his IPM consultant continue to fine-tune their approach to reduce the chance of slugs occurring. Otherwise, Trey has been very happy with the contributions from cover crops, as evidenced by the fact that he uses them on every acre of his farm. He has benefitted from cover crop payments through the Maryland Department of Agriculture and has appreciated participating in the state cover crop program, but feels that at this point he would continue even without the financial assistance. More recently, Trey was able to enroll some of his fields in a soil carbon program and receive extra payments for the soil carbon being sequestered by his cover crops and other management practices.

For farmers just getting started with cover crops, Trey recommends developing a plan and evaluating what goals they have for the cover crops. He feels he has benefitted from experimenting with a variety of approaches, so he recommends that other farmers be ready to test out a variety of cover crop methods and see what works for them.

Johnny Hunter, Castor River Farms (Missouri)

Johnny with his daughter and son in cover crops. Photo courtesy of Castor River Farms.

Johnny Hunter farms on flat alluvial soils in the Mississippi River Upper Delta area of Southeast Missouri, an area referred to as the Missouri Bootheel. His family farm is called Castor River Farms. He's farmed with a variety of crops over time, but at this point is mainly focused on soybeans and rice, with about 1,700 acres of soybeans and 800 acres of rice, mostly irrigated. Depending on the year, he may have some dryland corn or sorghum rotated with dryland soybeans.

Johnny first became motivated to try cover crops in 2013, because 2012 had been a bad drought year on his farm (and throughout much of the central and western U.S.). The crop failures he experienced in 2012 got him asking how he could improve the health and resiliency of his soil.

At that time, he had already reduced some tillage, but was still doing regular tillage every year to rehip planting beds (a practice of shaping the ground for irrigation furrows), often in combination with disking and use of a land plane to grade the fields. As part of his move to a more resilient farming system, he now has a near no-till system, with the only soil disturbance being to carve out a small water furrow approximately eight inches wide and 6-8 inches deep on 40-inch centers. The rest of the soil is undisturbed.

His change in land management also led him away from the traditional flood-irrigation method for rice production–an approach still used for the majority of rice production in the Missouri Bootheel. Johnny feels the combination of cover crops, no-till, and keeping furrow irrigation small has been effective in building soil health.

When he first started with cover crops almost a decade ago, he was primarily using a three-way mix of cereal rye, crimson clover, and radish. Now, depending on the season and goals for each field, he generally uses a more diverse mix–typically cereal rye with black-seeded oats, hairy vetch, crimson clover, dwarf Essex rapeseed, and radish. On heavier soils, he sometimes uses annual ryegrass with crimson clover and radish for the benefits of the extensive root system of the ryegrass. He characterizes his soil type as having primarily silty clay loam on about 70% of his fields, with the remainder being a heavier clay.

Cover crop planting and termination

All his cover crops are fall-seeded: either drilled right after harvest, or flown on into still-standing soybeans before harvest. When drilling the cover crop mix, he uses a 40-foot John Deere air-seeder drill, which is the same planter he uses for planting soybeans and rice.

Termination of cover crops is done through herbicide application using a broadcast sprayer. He sometimes plants soybeans into still-living cover crops, then sprays after planting. Otherwise, he tries to spray-terminate the cover crops about two weeks before expected planting.

Johnny said for planting green into crops, he pays attention to the growth stage of the cover crop, but also the soil temperature, air temperature, rainfall, and weed pressure. In his area, he also has to take into account whether black cutworms are showing up. He's seen cutworms in all types of field situations: where there are no cover crops, with early-terminated cover crops, and with late-terminated cover crops. He avoids using preventative insecticides and instead scouts for cutworms, applying insecticides only as needed. He feels that when cover crop growth is more robust, there is less cutworm pressure. When he has had a poor stand of cover crops is usually when he's had more cutworm pressure. He speculates that good cover crop growth may increase the number of predator insects that can suppress cutworms.

He has planted green into cover crops of varying sizes, including cereal rye up to six feet tall, but suggests to new growers that they terminate cover crops earlier. He commented that you need to encourage active soil biology to help break down a high-biomass cover crop before letting it grow too much.

For him, the benefits of planting green are weed control, keeping living roots in the soil as much as possible, and helping build a population of beneficial insects.

When seeding soybeans and rice with his John Deere drill, he hasn't had to make any adjustments for cover crop residue. Interestingly, he's found that his drill can still plant effectively down into the shallow irrigation furrows, providing some soil anchoring when water is running through the furrows.

Although Johnny does not have livestock, he recognizes the value of animal manure for the soil and tries to use 2-3 tons of chicken manure per acre on most of his fields on a rotating basis. In the future, he's interested in working with neighbors to set up some custom grazing on some of his fields.

Changes in fertility and weed management

When asked about how cover crops have impacted his fertilizer management, he reports having been able to reduce his phosphorus and potassium applications. In most fields, he can meet his phosphorus and potassium needs with chicken manure and has generally been able to build his fertility levels.

Cover crops have allowed him to reduce his nitrogen fertilizer applications on rice somewhat, depending on the cover crop growth. He evaluates that annually, doing some nitrate sampling in early spring. Generally, he finds the cover crops contribute about 30-70 units of nitrogen per acre, allowing him to reduce his applied nitrogen fertilizer by an equivalent amount.

Johnny has observed that cover crops have really helped with weed control. Herbicide-resistant types of pigweed are now common in his farming region, but no-till and cover cropping with rye has dramatically reduced that weed on his farm. In fields where he's had at least three years in a row of rye, he particularly notices much lower populations of herbicide-resistant pigweeds.

He commented that soils are used to supporting a diversity of plants, and so weeds happen to fill that shortage of diversity in monocultures. By having cover crop diversity, there is less opportunity for weeds to invade.

Use of cover crops has allowed him to be more strategic with herbicide application. He pays attention to the weeds in a field and adjusts to what's needed for control while keeping herbicide costs in check. If his residual herbicide is working well, he finds that about a third of the time he can skip doing a second post-emergence herbicide application, saving $25-$30 per acre when factoring in the cost of the herbicide, labor, fuel, and equipment costs.

He has also gone to using residual herbicides with shorter soil life.

He wants products that break down before fall to avoid injury to his cover crop mix, and feels these shorter residual herbicides are easier on the soil biology as well. Another benefit is that the residual herbicides he is using, such as metolachlor, are less expensive than some of the longer-lasting herbicides now on the market.

Changes in soil moisture and irrigation

With multiple years of cover cropping combined with no-till, Johnny has found his soils are now more resilient in the face of drought, as they have developed a much greater water holding capacity. He's been steadily building soil organic matter, which is adding to the water holding capacity of his soil.

A display of Castor River Farms products. Photo courtesy of Castor River Farms.

For his irrigated fields, he measures soil moisture at 4-, 8-, and 24-inch depths. He's found that rain or irrigation water soaks in faster than it used to, detecting soil water at 24 inches deep after one inch of rain.

With the better moisture-holding capacity of the soil and other soil health changes, he estimates they now use about one-third less irrigation water, which saves about $30 an acre (and even more than that now with higher fuel costs).

Summary thoughts

Overall, cover crops are saving Johnny money on herbicides, fertilizers, and irrigation costs, so he feels they are definitely improving his profitability. More than that, he feels the cover crops and no-till are making his farm more resilient to drought and weather extremes. Johnny has developed an impressive program of direct sales with cleaned and packaged food-grade rice, marketed under the Castor River Farms label. Having a sustainable production system contributes greatly to the marketability of his rice products. For more information on his rice and farm, see https://castorriverfarms.com

Johnny said, "Cover crops are one of the most important tools in our toolbox for our sustainability goals. And the next generation is very much on my mind–making sure the farm will be in good shape in 30, 40, 50 years." Johnny hopes his young son and daughter will be involved with the farm when they grow up. He understandably wants to leave the land and farm operation in good shape for them.

Asked about what he would say to farmers new to cover crops, Johnny said, "Be curious about healthy soils, and realize cover crops are a pathway to that. You need to take a holistic approach." He added that it's good to understand "your why"–why you are using cover crops. If you are just using cover crops to get a check, you'll be less likely to be successful with them. It's better to use cover crops with the goal of improving your soil resources. Surround yourself with people who know how to do it; that will help you reduce mistakes and achieve success sooner.

Larkin Martin (Alabama)

Larkin Martin. Photo courtesy of Larkin Martin.

Larkin Martin is a seventh-generation farmer in northern Alabama near the Tennessee river. Her family's farm operation is mostly on upland soils, with about 70%-80% of the fields being considered highly erodible. She also has some sandy, light-textured creek bottom ground. The total land area is about 7,000 acres, and she grows a diversity of crops–primarily cotton, soybeans, corn, and wheat. She has also experimented with smaller acreages of other crops, including canola, sesame, sorghum, and peanuts.

Larkin said she got serious about using cover crops on the farm in 2017, although she had tried growing a little cereal rye in previous years. She's been doing minimum tillage since 1993, with some fields in rotational no-till.

There were several reasons she decided she should start using cover crops. She wanted to:

- Control erosion in the months between fall harvest and spring planting
- Build organic matter (their soils are low organic matter)
- Provide a cover crop mulch layer in spring and summer to help with moisture retention–she doesn't have irrigation despite having droughty soils, so maintaining soil moisture is critical
- Condition the soil to reduce compaction from no-till
- Improve rainfall infiltration

She's still evaluating whether the cover crops are helping with weed control, but thinks they may be in some cases.

Early on, rye was difficult to buy in her area, so they grew a three- to four-way mix recommended by the USDA-NRCS. The mixes included legume, grass, and Brassica cover species. She has used both the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) to obtain financial support for cover crops. As she has observed the performance of the cover crop mixes, she's found that she likes growing more than one species at a time since different benefits are provided by different root systems and plant types.

Specific mixes she has used include:

- Oats, radish, and clover
- Cereal rye, radish, and clover
- Oats, cereal rye, radish, and clover

Crimson clover is usually her clover species of choice, but she's also tried berseem clover and white clover. She has also experimented with other mixes.

Nearly all of her corn fields go to a cover crop and then to cotton the next year. Corn is harvested in August or early September in their area, so she has plenty of time to establish a fall cover crop.

She has found that it's often beneficial to move cotton planting back about 7-10 days and have more growth on the cover crop. However, if cereal rye is in the mix, she tries to terminate it in a timely fashion; she prefers not to let it head out before planting. There have been some situations in which the rye got tall and then started lying down, making planting more difficult.

Cover crop seeding and termination

She normally spreads the cover crops with a big fertilizer spreader, mostly into corn stubble. After broadcasting the cover crop seed, she often incorporates it with a Phillips (Thompson) harrow to get better seed-to-soil contact.

One interesting approach she uses for termination in some fields is to spray a grass-killing herbicide (clethodim) that terminates the grass cover crop but allows the clover cover crop to keep growing and fix more nitrogen. Normally they put about 90 pounds of nitrogen fertilizer per acre on cotton, but she's been able to cut back in places to 70 pounds per acre. Radishes have sometimes winter-killed and in other years overwintered, so she has to factor that into the spring termination approach.

While cover crops have mostly had positive impacts on her farm, she has at times had a problem with slugs in her cotton fields, particularly affecting early-season cotton seedlings. In a few cases, she's had to replant an entire cotton field that was badly damaged by slugs during emergence.

Despite the occasional setbacks with slugs, Larkin said the merits of cover crops are strong enough to keep using them.

Benefits from the cover crops

Larkin commented on several benefits she's observed from cover crops. First of all, she commented on how fields that are no-till but not using cover crops can tend to have soil compaction; after adding cover crops to the no-till fields, she isn't seeing as much of a compaction problem. The covers have also helped noticeably in fields that have hardpans (dense soil layers restricting root growth) and tend to suffer from drought effects due to poor rooting. In the past, the cotton roots in those hardpan soils would turn sideways when they hit the hardpan layer, leading to what she termed a “J-hook” in the root. With the cover crops, she doesn’t see that nearly as much.

She feels that she is gradually building soil organic matter, which is really important in her sandy loam or sandy clay, both of which are often very low in soil organic matter (1% or less). One field that has been cover cropped for five straight years has already improved from 0.8% to 2.2% organic matter based on soil tests.

Asked what she would tell farmers not yet using covers, Larkin said, “The most important resource you have is the soil in your fields–cover crops will hold and improve the soil and are well worth the trouble.”

Junior Upton (Illinois)

Junior Upton. Photo by Ciji Taylor, NRCS.

At the time of this interview, Ralph "Junior" Upton farmed about 1,300 acres in southern Illinois (he retired from farming after the fall 2022 harvest). He started farming in 1964 and used cover crops on at least some fields throughout his farming career. Initially, he focused on using clover cover crops. He would overseed red, sweet, or ladino clover into winter wheat in February. The clover would become established in the spring, staying small under the wheat crop until the wheat was harvested in mid-summer. After wheat harvest, the clover would take off and grow through the fall. He'd normally try to cut the clover for hay in the fall, and sometimes get a seed harvest on the clover the next spring.

He first started no-tilling in about 1973. That transition was made possible when John Deere came out with double disk openers on their planters. Junior felt that previous planters wouldn't work for no-till.

In the 1980s, he started to hear a little bit more about the sustainability advantages of cover crops, so he started experimenting with more cover crop options. His farm's income was low during that period, so he focused on cover crop options that were affordable, trying buckwheat, hairy vetch, and cereal rye, primarily for weed control. The hairy vetch also had the advantage of providing some nitrogen fixation.

Buckwheat would be planted after wheat harvest in early July. If he had a market for the buckwheat, he would also consider harvesting it for seed. Some years, the buckwheat made a profit comparable to double crop soybeans, but eventually the market for buckwheat went away, so he stopped using it.

Junior then started planting cereal rye and hairy vetch together. For several years, he seeded the mix using a broadcast spreader. Then, when seed got more expensive, he started using a drill to economize on seeding rate and ensure that a higher percentage of the seed would establish. He harvested and kept his own rye and vetch seed, or occasionally bought rye from a neighbor.

Junior noted that his first use of cover crops was on ground he owned, and as he started to see the benefits over time, he gradually added cover crops on rented ground. He was initially a little reluctant to spend money on cover crop seed on rented ground, but now feels that the benefits are well worth it.

In recent years, his cover crop program has been to use cover crop mixes before both corn and soybeans. Before soybeans, he typically does a three-way mix of cereal rye (40 pounds per acre), annual ryegrass (4-6 pounds per acre), and rapeseed (2 pounds per acre). Before corn, he uses a three- to five-way mix, always including cereal rye (40 pounds per acre), annual ryegrass (4-6 pounds per acre), and hairy vetch (14 pounds per acre). If he can plant the mix early enough, he adds some rapeseed (2 pounds per acre) and spring oats

(8 pounds per acre). He feels the cereal rye is important for good erosion control. He likes annual ryegrass for its deep roots and ability to help address soil compaction. On wetter fields, annual ryegrass does well, even better than cereal rye. The oats provide quick fall growth.

He no longer routinely grows winter wheat for grain, in part because he doesn't like growing double crop beans, commenting that on hilly ground, soybean residue tends to float away, and gullies form after rainstorms. He feels the double crop beans don't leave enough time for a soil-protecting cover crop to become established in the fall.

On the occasions when he does plant some winter wheat, he plants a diverse cover crop mix following wheat harvest to improve the soil, finding that it substantially helps his corn crop the next year.

Junior has been a 100% no-till farmer for 15 years and tries to plant cover crops on all his fields, but for quite a few years he has done strip trials with and without cover crops in 80-foot strips. The cover crop strips have yielded better than the strips without cover crops every year, which he attributes to the better soil health from the cover crops.

Cover crop seeding method

Junior has tried a variety of broadcast seeding methods for cover crops, including helicopters and fertilizer spreaders. He hasn't been satisfied with broadcast seeding compared to using a drill because he doesn't see as good of establishment from the broadcast seeding. He noted that he has a lot of crop residue and it's hard to ensure good seed-to-soil contact when broadcast seeding. Ideally, he would like to overseed cover crops in early September with aerial seeding, but observed that aerial seeding costs more money than drilling it himself; plus, he can keep seeding rates lower with the drill and sees good establishment with the drill.

Cover crop termination method

Prior to corn planting, Junior applies a grass herbicide to terminate the cereal rye and annual ryegrass early, but lets the hairy vetch keep growing (in some years the annual ryegrass may not completely die, but hairy vetch seems to choke it out). Ideally, he lets the cover crops turn green and start growing before spraying, once they are over about "shoe-top" high. He terminates the grass cover crops early before corn because he doesn't want the cereal rye to tie up nitrogen.

He does delay his corn planting a little compared to neighbors in order to allow more time for the hairy vetch to fix nitrogen. His goal is to let the hairy vetch grow long enough to contribute about 70 pounds of nitrogen per acre, so he lets it grow through early May and tries to plant corn around May 10. He finds that the hairy vetch is easy to plant into until it starts blooming, but then it gets viny and harder to plant into, though it can still be done with the right planting equipment. He terminates the vetch with a mix of 2,4-D and glyphosate shortly after corn planting. He uses some starter fertilizer with corn to help it sprout.

His approach with soybean planting is to plant green into the still-living cover crops and then spray terminate the covers after soybean planting. He does monitor the cover crop height and prefers not to let it get too tall. He has his ag retailer spray glyphosate to terminate the covers (a mix of cereal rye, annual ryegrass, and rapeseed).

Impacts of the cover crops

Many of Junior's fields, like his neighbors' in southern Illinois, suffer from fragipans, which are dense subsoil layers that restrict root growth and water penetration. The existence of fragipans can greatly reduce crop yields because crops like corn and soybeans have less soil moisture and can't grow roots as deep. Soil scientists doing research on Junior's farm found that multi-year use of annual ryegrass and other cover crops seemed to be causing his fragipan soil restrictions to disappear, leading to dramatic yield gains–as much as 40 bushels or more with corn. Follow-up research by a group of University of Kentucky soil scientists found annual ryegrass releases chemicals from deep-growing roots that are effective in breaking up fragipans.

In the past, the only tool that could be used with fragipans was a deep soil ripper, but that provided limited and only short-term benefits, whereas Junior said the cover crops have been a much more effective and long-lasting solution.

Junior commented that cover crops can be deceptive, growing roots much deeper than one would expect from looking at their above-ground growth. Working with former University of Illinois agronomist Mike Plumer, Junior found that annual ryegrass had roots 70 inches deep in February while above ground growth was only four inches tall. The following August, they dug soil pits for a field tour on the farm and found the corn roots going down that deep following the cover crop root channels instead of being restricted to the upper soil horizon, as would have been the case on conventionally farmed ground.

Collaborating agronomists working with Junior have documented that soil organic matter on his first cover crop research project was at 0.8% and has now climbed to 3.5% through the long-term combination of no-till and diverse cover crop mixes.

Between the deeper cash crop rooting and higher moisture-holding capacity from higher soil organic matter, Junior said over crops have really helped in dry weather: “No doubt about it!” He commented that corn fields that, in the past, would get very moisture-stressed in 10 days can now go 4-5 weeks without rain.

After using his no-till cover crop system for a number of years, Junior said he can see very noticeable changes to the soil compared to newly rented fields or neighbors’ farms. He has significantly better soil structure, more earthworms, and darker soil color. He recently had a company come in to do some drainage tile work, and the tile installer commented on how much darker his soils were than nearby fields where they had put in tile.

Some tips that Junior had for farmers considering using cover crops:

- Erosion control is the most important benefit, and you’ll see it right away.
- Weed control benefits also show up pretty quickly.

- You can get some nitrogen from legumes, but other fertility benefits can take some time as soil health gets better.
- Benefits in dry weather are also significant, but improve over time as soil gets better.
- Think about your rotation and how best to fit in the cover crops.
- Be sure to figure out adjustments to planting equipment for planting into cover crop residue, or consider getting a different planter.
- Experiment with strips of different cover crops to see what works best for you.

When asked about how cover crops had impacted profitability, Junior said the farm probably wouldn't have been able to stay afloat financially without the cover crop and no-till system due to poor profits in conventional fields. In his experience, the cover crops have paid for themselves with improved yields and improved profitability.

Kent and Kyle Wasson (Montana)

Four generations of the Wassons, with Kyle in the center and Kent on the right.

Kent Wasson farms and ranches with his son Kyle in north central Montana, close to the Canadian border. They have about 12,000 acres of cropland and graze about 18,000 acres of summer rangeland with beef cattle. The cropping system is centered on spring wheat, with about a third of the acreage in pulses (large-seed legumes)–mainly yellow peas, but also some lentils where the soils are suitable. They rotate in some oilseed crops, too–particularly flax and canola. The oilseeds do best on plateau "benches" and serve well as rotation crops with the wheat.

Kent's original motivation to use cover crops came from attending the First National Conference on Cover Crops and Soil Health in early 2014. He went home from that conference and decided they needed to try growing some cover crops on their farm, even though they are in a low-rainfall area where cover crops had been less common.

That first year, they grew 200 acres of cover crops, with the goal of obtaining some soil enhancement. They used a mix of about 17 diverse species, including legumes, radishes and other Brassicas, cowpeas, chickpeas, lentils, millets, and other species. Most of their fields consist of sandy clay loam soil. In some places, the topsoil is quite shallow, and underlain by gravel.

They have used the cover crops to target improvement of some of their heavier-textured ground where it's been difficult to get sufficient rainfall infiltration. In some years, they've done two back-to-back years of highly diverse cover crops from spring through fall to try to improve the soil. Generally, they try to plant 300-500 acres of cover crops each year, rotating where they plant them to gradually build up the soil health of their fields.

Organic matter used to be very low in most of their grain fields, at about 0.8%-0.9%. Now, in fields where they've done multiple years of cover cropping, the soil organic matter has almost doubled to about 1.8%-1.9%. Kent hopes that continued cover cropping will help them increase their soil organic matter to about 2.5%, which would create significantly greater water holding capacity in their soil–something badly needed in a low-rainfall area.

Besides the gradual change in soil organic matter, Kent commented that they are getting to the point where water doesn't stand in their fields any more after a hard rain; it's soaking in much better.

Cover crops have also helped with weed issues. They've been in no-till or minimum-till for 30 years, but certain weeds have adapted to that system, such as foxtail. A healthy stand of a cover crop or cover crop mix helps control the foxtail and other weeds.

So far, they have kept fertilizers at the same level following cover crops. However, they have noticed better productivity after the cover crops, including for grain quality. For example, when they grow durum wheat or other wheats the year after cover crops, the wheat is higher-quality, normally achieving #1 grade and 1.5% better protein, earning a premium.

While they use cover crop mixes primarily to improve the soil in rotation with annual crops, they also use them to make income through grazing of beef cattle. For example, one year, following good summer growth of a cover crop mix that had been seeded in mid-May, they turned cattle into the fields in mid-September. At that stage the steers averaged 425 pounds of weight. Utilizing 500 acres of cover crops for grazing, the steers routinely walked a mile to water and then back to the cover crops. The steers gained a remarkable 4.1 pounds per day after about seven weeks of grazing, at which point their average weight was 638 pounds.

Sometimes the Wassons graze the cover crop mix from early fall all the way to early January, but water access can be a limiting factor.

Kyle out in a diverse summer cover crop mix.

Cows grazing cover crop residue in midst of a three-day snowstorm.

The cattle are not fenced into the cover crop acres, but will go to them preferentially until the forage is used up. Usually, they have about 400-500 head of cattle grazing the cover crops. When the cover crop forage is finished, the cows eat some standing barley hay, eat baled hay that is hauled to them, or go onto rangeland until they're ready for market.

When I visited with Kent in winter of 2022, he commented that during the past year (2021), the cover crop plantings were really the only green summer fields on their farm. Climatologists called what the Wassons were experiencing a "200-year drought." With so little in the way of green plants, they suffered an invasion of grasshoppers on the cover crop fields, with the hoppers eating most of the low-growing covers but leaving the taller sorghum and millet. Those

Images of the varying terrain on the Wassons's Spring Coulee Ranch, with summer rangeland at top and flatter wheat ground at bottom.

tough summer cover crop grasses provided some badly needed forage for their cattle.

Kent shared that they've paid an average of $30 per acre for their cover crop seed mix in the last few years, but he feels that it's been a very profitable investment, because of both soil improvement and cattle grazing. He commented that their approach of grazing the cattle on cover crops came second chronologically; at first, their focus was solely on soil improvement via the covers. Kent and Kyle keep experimenting with the mix of cover crop species being used. They've gradually cut back some on use of pulses because of expense, but they do typically include some cowpeas in the mix. Other common species in their mixes are radishes, turnips, various millets, sorghum, grazing corn, sunflowers, and sometimes buckwheat. The cover crops are planted with a 70-foot-wide air drill.

Where the cover crop mix has been rotated with wheat, Kent doesn't think he's seen a consistent yield improvement, but he has noticed less foliar diseases on the wheat, perhaps because the cover crops provide some diversity in the rotation. The real difference in yield came this past year with the severe drought; while many neighbors' wheat fields didn't produce enough grain to be worth harvesting, the Wassons were able to get a modest harvest off the majority of their fields, though of course yields were well below normal.

Kent attributed that better drought performance to better rainfall infiltration and improved soil moisture holding capacity following use of cover crops. Where they've used cover crops, he can also tell the soil tilth is better. For example, when seeding wheat with an air drill, he commented that the soil flows better around the furrow openers, and they don't have as much soil crusting as they used to.

Asked what he would say to other farmers in his region interested in cover crops, Kent commented: "It's good to try a diverse mix. Take a day to seed the cover crops in the middle of planting wheat or spring pulses." To make sure they get the summer cover crops seeded in a timely fashion for soil improvement, Kent tries to set aside a specific day on the calendar, like May 12, and puts aside wheat planting for a day in order to get the cover crops planted. He added: "Implement a five-year plan with the cover crops. Get a double dip for soil health and for your cattle–better soil quality and more weight on the cattle, a real win-win situation."

Justin and Molly Zahradka (North Dakota)

Justin and Molly Zahradka with their daughter. Photo courtesy of the Zahradkas.

Justin Zahradka and his wife Molly farm about 1,400 acres in the northeast part of North Dakota. Their farm is split about half-and-half between tillable cropland and pasture. Their cash crops are primarily soybeans and wheat, but Justin has also grown some corn and pinto beans and tried canola. Although the row crops are an important part of his operation, his primary focus is on livestock, which he grazes not only on pastures but also on cover crops. In fact, he relies on a neighbor to plant his row crops, saving money by not buying a planter so he can invest in the livestock part of his operation. He trades labor with the neighbor who does the planting, which is an approach that benefits them both. Molly helps out with the farm while also teaching vo-ag full-time. For their livestock system, they graze cattle and sheep and have a flock of chickens, as well.

Justin first got involved in cover crops as part of a Future Farmers of America (FFA) project, when he wanted to try doing some test comparisons of cover crops for grazing. That work not only provided data that proved to him the merits of cover crops, but contributed to him receiving the prestigious FFA National Star Farmer in AgriScience award in 2015. Since then, Justin has continued to test various approaches to grazing cover crops, always keeping an eye on data and profitability.

The first fields on which he tried cover crops for grazing in high school were part of a conventionally tilled farm, but now that he is farming for himself, he is using a no-till system, only pulling out a tillage tool if there are significant ruts in a field.

His initial cover crop mix for fall grazing was a summer-planted field of sorghum-sudan, barley, radishes, turnips, and peas. After several years of using cover crops, though he continues to experiment, he has some preferred approaches depending on the timing in the crop rotation.

After August harvest of small grains, he uses radishes and turnips for fall grazing if there is adequate soil moisture. Following a soybean or pinto bean crop, he uses cereal rye and focuses on grazing the rye in spring instead of fall. The winter-hardiness of cereal rye is a big plus in his experience. After spring-grazing rye, he has those fields planted to either a hay crop or possibly back to soybeans. He plants soybeans or hay after grazing. Overall, about a third of his row crop acres are planted into a cover crop each year, and most of the cover crops are grazed.

Details on grazing of cover crops

Justin normally grazes fall-planted radishes and turnips at 2-4 inches tall. With cereal rye, he normally waits to spring-graze. He feels that,

At top: Cattle fall grazing cover crops. At bottom: Cattle grazing cereal rye on the Zahradka farm. Photos courtesy of the Zahradkas.

in his area, there is a good two-week window for spring grazing, which he tries to do before the rye heads out; once the rye seed heads have formed, the cattle don't like eating the rye as well. Typically, he mob-grazes the rye when it's about 8-12 inches tall, depending on the weather. If anything, he errs on the side of earlier grazing since the rye can grow fast in spring.

He keeps grazing costs down and simplifies creating grazing paddocks by using portable electric poly wire with step-in posts. Some of the water for grazing comes from the prairie potholes (natural ponds) that occur on most of his fields. If he has an area without water, he hauls in water in a 2,200 gallon trailer, letting the trailer drain into portable tanks that the cattle drink from.

He normally moves his cattle and sheep regularly between paddocks, sometimes on a two-day interval and sometimes up to every two weeks. If the heifers are calving, he'll let them stay longer in a paddock so they aren't stressed by handling. He has gone to calving in early May in his current system.

Besides some significant economic benefits from grazing, Justin has also noticed health benefits for his cattle. Compared to cattle kept in a "dry lot," those being grazed on cover crops show a shinier coat of hair. He also hasn't had to spend money on vaccinations for his cattle for the last four years since herd health is so good.

By using cover crops as part of his crop rotation and consequently improving his farm's soil health, he's been able to cut back his fertilizer inputs by about 30%, and sometimes more. The overall system also saves on feed costs for his livestock. In 2021, a dry year, the cover-cropped areas had better yields due to their better soil moisture retention. He feels the benefits of his system are definitely paying for the cost of cover crop seed and that this system is the right long-term approach to take.

Cover crop seeding and termination method

Ideally, Justin uses a drill to seed his cover crops. However, he has had success broadcasting radishes and turnips; the smallness of their seeds helps them make good enough soil contact to germinate and grow.

After grazing rye, he lets it regrow just a little to improve herbicide translocation, then sprays to terminate it, often when the regrowing rye is just a few inches tall.

He occasionally ends up with a rye field that has not been grazed. In this situation, he plants green, adjusting the soybean planting date and termination timing based on available soil moisture.

Changes in soil from cover crops and grazing

He has noticed a definite improvement in soil structure, which happened fairly quickly in his loamy soils. Working with recently retired NRCS Soil Health Specialist Jay Fuhrer, he has documented significantly better rainfall infiltration rates on the fields with cover crops compared to adjacent areas with no cover crops.

In 2021, he seeded his cash crops into no-till cover crop residue and found that this system led to better soil moisture retention. When he did finally get an inch of rain in June, it soaked in very well on his cover-cropped fields.

His thoughts for farmers just getting started with cover crops are:

- Start small and take it seriously; put some time and thought into it.
- Cover crops help stop erosion.
- There are good benefits from grazing cover crops.
- Finding a mentor or someone to work with who has used cover crops can really help.

Justin says he's motivated to keep using cover crops in part because he sees a lot of dirt blowing in his county and it's frustrating to him to see that soil loss happening. He also feels he's better off economically using his system of combining cover crops with grazing as opposed to not, since the cover crops pay for themselves and provide so many benefits.

EPILOGUE

Can you afford not to use cover crops?

One morning, I saw a video segment on the national U.S. Farm Report featuring Mitchell Hora, a young Iowa farmer. Mitchell got an agronomy degree from Iowa State University and after returning to the family farm, became passionate enough about soil health that he decided to start a company called Continuum Ag to advise other farmers on soil health while continuing to jointly farm with his dad. Mitchell made a very effective point, that he has come to realize that cover crops are too often viewed as only a defensive strategy, simply protecting the soil. He is encouraging fellow farmers to see cover crops as a strategy for offense, in his case part of his strategy for controlling herbicide-resistant weeds, increasing his nutrient management efficiency, and improving his soil moisture management.

Mitchell is one of thousands of farmers who have come to recognize the many benefits of cover crops and improved soil health. When you think about it, the health of any farm starts with the health of the soil. It's often said that healthier soil leads to healthier profits. I think we also have to recognize that healthier soils can do a lot to reduce the stress of farming in the way that they improve resiliency in the face of challenging weather conditions, whether the weather is too wet or too dry. And many farmers I've talked to have shared how they are enjoying farming more as they have implemented cover crops and begun to follow their progress with improving soil health. When you think about it, having a living green cover all around your farm is a much preferable sight than bare dirt that is losing organic matter and subject to washing or blowing away. Those cover crops will be hard at work improving your soil while you're on winter vacation and enjoying more family time. This quality of life impact is just one more benefit you can realize with cover crops, to go along with the others captured by the book's subtitle, "Improving Soil Health, Profitability and Stewardship."

While the needs on each farm are different, I know of no other agronomic management tool that is so versatile in providing advantages

A beautiful field of crimson clover cover crop in mid-spring, contributing to the health of the soil and the land.

for helping manage a farm successfully. I made the analogy earlier in the book of cover crops as the Swiss Army Knife tool in terms of their versatility in providing management benefits. If you are like me and enjoy trying different tools, I truly believe cover crops are the best new tool you can try in your farming operation to improve success.

I understand the cost of cover crop seed can make some hesitate to try them, but there's never been more financial support available from USDA, state, and private sector sources to offset the cost of cover crop seed. And many of those sources will provide those dollars very easily. You may be able to easily get cover crop funds by working with your seed company, state commodity group, or the local county office for your soil and water district or NRCS.

I also understand that many farmers may feel like they don't have time in the fall to deal with planting a cover crop. That really shouldn't be a barrier, as there are now many companies that will provide cover crop seeding services, including fertilizer dealers, aerial applicators, and often other farmers who will bring in a drill to seed your cover crops. Using cover crops doesn't have to take any extra time on your part. In fact, since cover crops work well with no-till or other reduced tillage strategies, they can be part of a labor-saving system that gives you more time for other activities.

There's plenty of good technical assistance available these days on cover crops, not only through NRCS and Extension but also local agronomists, websites, and videos on cover crops including the SARE program (www.sare.org/covercrops) or your regional cover crop council (do a search for "cover crop council" and Midwest, Southern, Northeastern, or Western for your region). Best of all, find another farmer in your county doing cover crops and ask them about their experience. Most are glad to share what they've experienced and help you achieve success.

Ultimately, there are short-term and long-term horizons that come into play with cover crops. In the short-term is addressing what you can do to improve your farming operation this year. Strictly in those terms, there are a variety of steps you can take, whether it's an equipment upgrade, better pest management, using an improved crop variety, or trying cover crops. Cover crops can start to help right away, boosting earthworm numbers and stimulating soil biology, holding the soil in place, starting to improve rainfall infiltration, and helping with weed management. For livestock producers, cover crops are a great way to help provide more forage and manage nutrients from field manure applications.

Looking at a longer time horizon, if you are working to build your farm's prosperity and leave the farm in better shape for the next generation, there's really no better tool than cover crops. If you can increase the health of your soil over time, as many cover croppers have done, you can increase the water holding capacity of your soil. You can build your soil's inherent fertility. You can make that soil better able to tolerate droughts and big rainstorms. What better way to leave a lasting legacy for the next generation while at the same time improving your farming prospects for years to come?

Best wishes in your soil health journey!

Cover crops are an old practice made new with innovative management approaches, new types of cover crops, and updated equipment technology. The drive for more use of cover crops is rooted in a desire to improve both soil health and profitability, as well as protect our valuable soil for future generations. The USDA Sustainable Agriculture Research and Education program has long supported research and education projects on cover crops.

This book is intended for farmers considering cover crops, or those who recently adopted cover crops and want to improve their management. It will also be helpful to agronomists and other farm advisors. The book addresses a wide variety of cover crop management topics, including how to use cover crops in a time-efficient manner and adapt their use to the particular needs of a given farm. The second edition includes new chapters on grazing cover crops, using cover crops in horticulture, and cover crops in organic systems.

Dr. Rob Myers is an agronomist at the University of Missouri and one of the most widely known experts on cover crops in the United States, having decades of experience with cover crops. In 2022, his broadly impactful work with cover crops was recognized by the American Society of Agronomy with the national Agronomic Education and Extension Award. Dr. Myers grew up on a grain farm in central Illinois, which he continues to help manage and which is 100% cover cropped.

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