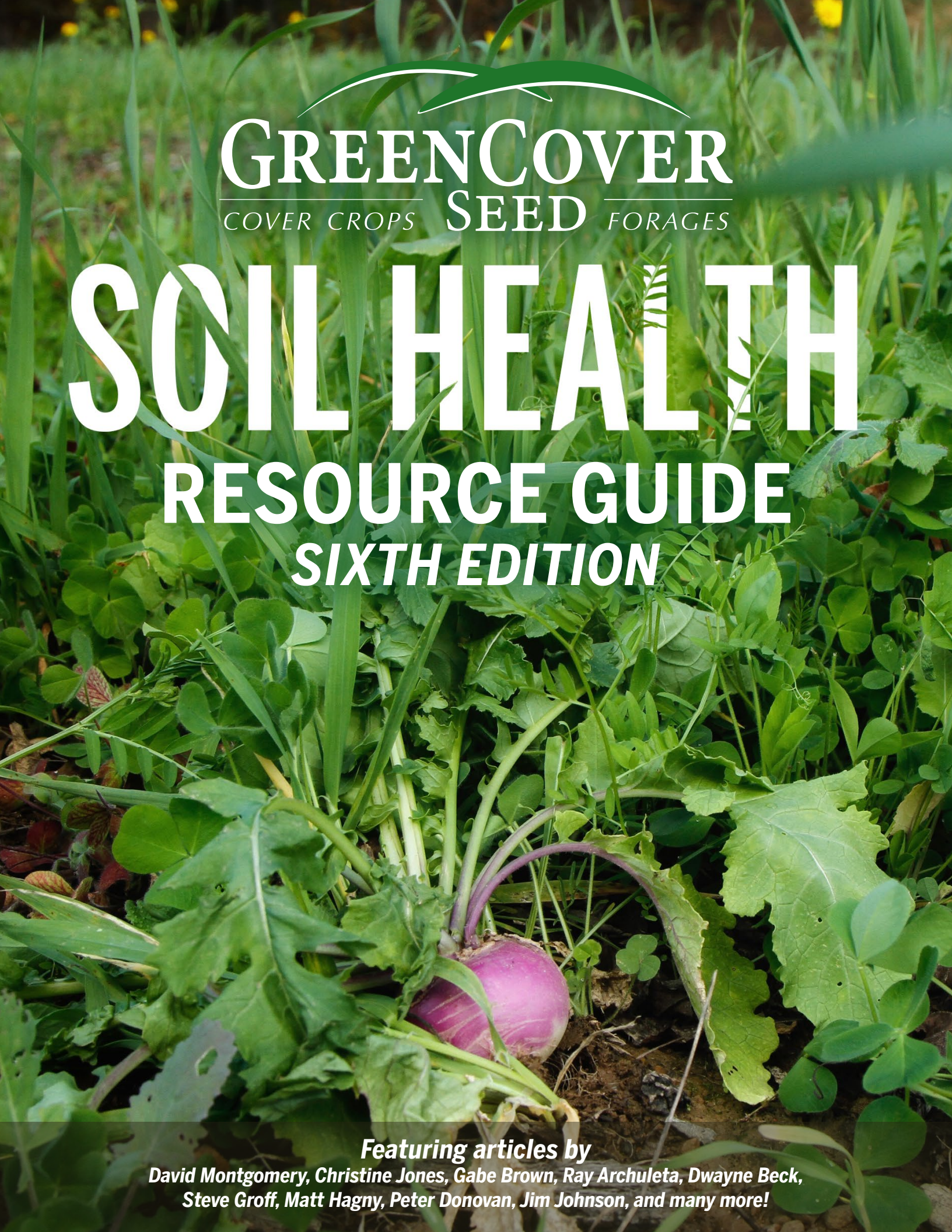

GreenCover SEED

COVER CROPS FORAGES

SOIL HEALTH RESOURCE GUIDE

SIXTH EDITION

Featuring articles by

David Montgomery, Christine Jones, Gabe Brown, Ray Archuleta, Dwayne Beck, Steve Groff, Matt Hagny, Peter Donovan, Jim Johnson, and many more!

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Cover Photo by Daniel Collier. Pictured is the Drop-Tine Fall Reload Mix

THE PURPOSE OF THIS GUIDE

At Green Cover Seed, our mission is **to help farmers and ranchers regenerate God's creation for future generations**. As producers who make our living from the abundant resources that God has blessed us with, we should be the most adamant and passionate conservationists. Not only do our current and future livelihoods depend on healthy functioning soils and ecosystems, but God has charged us with caring for His creation. Adam, the first farmer, was directed by his Creator to care for and protect the soil. At Green Cover Seed, we believe that we still have this responsibility, and we are called to take the additional step of rebuilding and regenerating our soils. We are committed to educate as many people as possible about soil health, and provide as many tools and resources as we can. This Soil Health Resource Guide is dedicated to that end.

We acknowledge our own limited knowledge and experience, so we have invited some of the best minds in the Regenerative Agriculture movement to share their valuable expertise and insight for the benefit of all. For some, this Guide may be a reinforcement for what they already know; to others, it may be the first step in the journey towards healthier soils. This is by no means an exhaustive resource in soil health; rather it is intended to be a concise and simple summary of the big concepts and a gateway to deeper learning and explanations in other formats. Think of this Guide as a number of seeds that can sprout and grow into deeper understanding if you will but plant them.

Many of the articles in this Guide are summaries. The full article, supporting video, and presentations are easily searchable on our website: www.greencoverseed.com.

We invite you to do your due diligence and further explore any or all of the topics that we will touch on in this Resource Guide. We would be glad to hear your comments and feedback on this Guide, and are happy to provide additional copies upon request.

Keith and Brian Berns, founders

Diversity in the Soil

It has been observed that a mixture of plants often performs better than a monoculture of the best performing plant in the mix, an observation that defies "common sense". The secret to making this work lies in each plant species having unique liquid carbon root exudates which provides a balanced diet of sugar, energy, proteins, and nutrients, allowing the microbial population to increase dramatically. Plants surrounded by healthy, abundant microbial communities are more drought tolerant, are better supplied with plant nutrients, and more resistant to disease. In addition, all this microbial activity increases soil organic matter and improves soil structure.

Diversity in Learning

Diversity is a powerful force for people as well, and we benefit greatly from diversity in our food, friends, economy, and education! For this reason we strive to have significant new content every year for this Soil Health Resource Guide from a diverse array of soil health experts from around the world. While that is a good thing, it also means that many excellent articles from previous editions are not printed in this current edition. Fortunately, we do have all of these available on our website.

We encourage you to diversify your education and read these articles also. Let the learning continue by going to **www.greencoverseed.com/SHRG**!

Scan this QR code to go directly to the Soil Health Resource Guide on our website.

> *"I just wanted to write you a quick note to say thanks. I really appreciate all the help and advice that you have given me over the last year. I am new to farming so you have been a wealth of knowledge on how to improve our grazing and rebuild our soil nutrition. We are a small operation but that has never affected the level of customer support that we have received."*
>
> Scott B, Alabama

Past Articles Available on Our Website

Soil Health Science

- *Biotesting Information (PLFA), Haney Soil Testing* by Lance Gunderson
- *Diversity and Pest Management* by Jonathan Lundgren
- *Fungal Assets* by Wendy Taheri
- *Everything You Ever Needed to Know About Mycorrhizal Fungi* by Dale Strickler
- *Carbonomics* by Keith Berns
- *The Secret Behind the Power of Diversity*
- *Carbon to Nitrogen Ratio*
- *Cover Crop Plant Tissue Testing*

Applied Soil Health

- *Living Roots as Often as Possible* by Jay Fuhrer
- *Minimize Soil Disturbance* by Keith Berns
- *Keep the Soil Covered* by Rolf Derpsch
- *A Case Study of Soil Improvement* by Kevin Schilthuis
- *Spring Green Manure* by Burkey Farms
- *Poly Cropping with Multiple Cash Crops* by Axten Farms
- *Hail Damage and Cover Crops*
- *Summer Fallow Cover Crops*
- *Corn & Soybean Rotation Ideas*
- *The Drought Resilient Farm* by Dale Strickler
- *Plant a Cover Crop? But I'll Use Up All My Moisture!*
- *Highboy Seeding*
- *Aerial Seeding*
- *Have You Considered Frost Seeding?*

Soil Health and Grazing

- *Adaptive Grazing Management* by Allen Williams
- *Grassfed Beef and Soil Health: Profit & Promise* by Tim Goodnight - Pharo Cattle
- *Improving Pasture Health: Bring Back Dung Beetles* by Brett Peshek
- *Multi Species Grazing: A Primer on Diversity*
- *Pasture Management for Horses*
- *Ley Farming and Forbs: The Forgotten Third Component of Pasture* by Dale Strickler
- *Nitrate Poisoning*
- *Supplemental Grazing*
- *Which Cover Crops are Best for Grazing*
- *Adaptive Multi-Paddock Grazing*
- *Interseeding Into Warm Season Grasses*
- *Interseeding Summer Annuals into Cool Season Grass Sods*
- *Livestock Grazing and Stocking Rates*
- *Full Season Cover Crop Grazing*

One of the biggest modern myths about agriculture is that organic farming is inherently sustainable. It can be, but it isn't necessarily. After all, soil erosion from chemical-free tilled fields undermined the Roman Empire and other ancient societies around the world. Other myths also hinder recognizing the potential to restore degraded soils to feed the world through Regenerative Agriculture.

When I embarked on a six-month trip to visit farms around the world to research my book, "Growing a Revolution: Bringing Our Soil Back to Life," the innovative farmers I met showed me that regenerative farming practices can restore the world's agricultural soils. In both the developed and developing worlds, these farmers rapidly rebuilt the fertility of their degraded soil, which then allowed them to maintain high yields using far less fertilizer and fewer pesticides.

Their experiences, and the results that I saw on their farms in North and South Dakota, Ohio, Pennsylvania, Ghana and Costa Rica, offer compelling evidence that the key to sustaining highly productive agriculture lies in rebuilding healthy, fertile soil. This journey also led me to question three pillars of conventional wisdom about today's industrialized agrochemical agriculture: that it feeds the world, is a more efficient way to produce food and will be necessary to feed the future.

Myth 1: Large-scale agriculture feeds the world today

According to a recent U.N. Food and Agriculture Organization (FAO) report, family farms produce over three-quarters of the world's food. The FAO also estimates that almost three-quarters of all farms worldwide are smaller than one hectare – about 2.5 acres. Only about 1 percent of Americans are farmers today, yet most of the world's farmers work the land to feed themselves and their families. So while industrialized agriculture feeds the developed world, most of the world's farmers work small family farms. A 2016 Environmental Working Group report found that almost 90 percent of U.S. agricultural exports went to developed countries with few hungry people.

Of course the world needs commercial agriculture, unless we all want to live on and work our own farms. But are large industrial farms really the best, let alone the only, way forward? This question leads us to a second myth.

Myth 2: Large farms are more efficient

Many high-volume industrial processes exhibit efficiencies at large scale that decrease inputs per unit of production. The more widgets you make, the more efficiently you can make each one. But agriculture is different. A 1989 National Research Council study concluded that "well-managed alternative farming systems nearly always use less synthetic chemical pesticides, fertilizers, and antibiotics per unit of production than conventional farms."

And while mechanization can provide cost and labor efficiencies on large farms, bigger farms do not necessarily produce more food. According to a 1992 agricultural census report, small, diversified farms produce more than twice as much food per acre than large farms do. While large farms excel at producing a lot of a particular crop – like corn or wheat – small diversified farms produce more food and more kinds of food per acre overall.

Photo by Will Metts

Myth 3: Conventional farming is necessary to feed the world

We've all heard proponents of conventional agriculture claim that organic farming is a recipe for global starvation because it produces lower yields. The most extensive yield comparison to date, a 2015 meta-analysis of 115 studies, found that organic production averaged almost 20 percent less than conventionally grown crops, a finding similar to those of prior studies. But the study went a step further, comparing crop yields on conventional farms to those on organic farms where cover crops were planted and crops were rotated to build soil health. These techniques shrank the yield gap to below 10 percent.

The authors concluded that the actual gap may be much smaller, as they found "evidence of bias in the meta-dataset toward studies reporting higher conventional yields." In other words, the basis for claims that organic or regenerative agriculture can't feed the world depend as much on specific farming methods as on the type of farm.

Consider too that about a quarter of all food produced worldwide is never eaten. Each year the United States alone throws out 133 billion pounds of food, more than enough

to feed the nearly 50 million Americans who regularly face hunger. So even taken at face value, the oft-cited yield gap between conventional and organic farming is smaller than the amount of food we routinely throw away.

Building healthy soil

Conventional farming practices that degrade soil health undermine humanity's ability to continue feeding everyone over the long run. Regenerative practices like those used on the farms and ranches I visited show that we can readily improve soil fertility on both large farms in the U.S. and on small subsistence farms in the tropics.

I no longer see debates about the future of agriculture as simply conventional versus organic. In my view, we've oversimplified the complexity of the land and underutilized the ingenuity of farmers. I now see adopting farming practices that build soil health as the key to a stable and resilient agriculture. And the farmers I visited had cracked this code, adapting no-till methods, cover cropping, and complex rotations to their particular soil, environmental, and socioeconomic conditions.

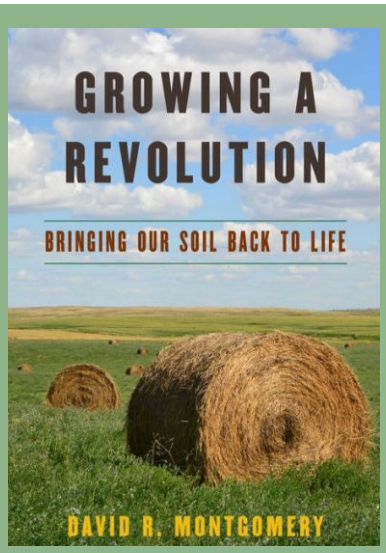
Whether they were organic or still used some fertilizers and pesticides, the farms I visited that adopted this transformational suite of practices all reported harvests that consistently matched or exceeded those from neighboring conventional farms after a short transition period. Another message was as simple as it was clear: Farmers who restored their soil used fewer inputs to produce higher yields, which translated into higher profits.

No matter how one looks at it, we can be certain that agriculture will soon face another revolution. For agriculture today runs on abundant, cheap oil for fuel and to make fertilizer – and our supply of cheap oil will not last forever. There are already enough people on the planet that we have less than a year's supply of food for the global population on hand at any one time. This simple fact has critical implications for society.

So how do we speed the adoption of a more resilient agriculture? Creating demonstration farms would help, as would carrying out system-scale research to evaluate what works best to adapt specific practices to general principles in different settings. We also need to reframe our agricultural policies and subsidies. It makes no sense to continue incentivizing conventional practices that degrade soil fertility. We must begin supporting and rewarding farmers who adopt regenerative practices.

Once we see through myths of modern agriculture, practices that build soil health become the lens through which to assess strategies for feeding us all over the long haul. Why am I so confident that regenerative farming practices can prove both productive and economical? The farmers I met showed me they already are.

By David Montgomery, Ph. D • Seattle, WA
David R. Montgomery is a MacArthur Fellow and professor of geomorphology at the University of Washington.



For centuries, agricultural practices have eroded the soil that farming depends on, stripping it of the organic matter vital to its productivity. Now conventional agriculture is threatening disaster for the world's growing population. In "Growing a Revolution", geologist David R. Montgomery travels the world, meeting farmers at the forefront of an agricultural movement to restore soil health. From Kansas to Ghana, he sees why adopting the three tenets of conservation agriculture—ditching the plow, planting cover crops, and growing a diversity of crops—is the solution. When farmers restore fertility to the land, this helps feed the world, cool the planet, reduce pollution, and return profitability to family farms.

We often hear producers who use cover crops state that they practice "Regenerative Agriculture." But what is "Regenerative Agriculture?" Regenerative Agriculture is an understanding. It is an understanding that one must work with nature instead of against her. The deep, rich topsoil which once covered a large percentage of North America was the result of a healthy, functioning soil ecosystem. Sunlight, water, minerals, plants, mammals, insects, and micro-organisms all working in harmony.


Photo by Ron Sedlock

Unfortunately, today much of the current production model is about man trying to impose his will on nature. We have an infiltration problem and we till the field rather than grow a cover crop to build soil aggregates. We see a pest and we spray a pesticide, rather than providing habitat for predator insects which would kill the pest. We have low yields, so we add more synthetic fertilizer rather than feeding soil life with diverse root exudates. We treat symptoms instead of solving the real problem.

The result is a degraded resource. What was once thick, deep topsoil is now but a mere fraction of what it was. I have the good fortune of being on hundreds of farms and ranches all over North America every year and I have never been on an operation, including my own, that is not degraded. As producers, we have come to accept that degraded resource. But if we follow nature's template, using the five principles of a healthy ecosystem, we can regenerate our resources.

Those five principles are:

1. Armor on the soil surface.
2. Least amount of chemical and physical disturbance possible.
3. Diversity of plants and animals, including insects.
4. Living roots in the soil as long as possible throughout the year.
5. Animals integrated into the system.

These five principles are the same anywhere in the world where plants can grow. The "tools" we use to accomplish these principles may differ, such as which cash or cover crops we grow or which species of livestock we raise, but the principles are the same.

By reducing and eliminating tillage, infiltration rates, water holding capacity, and nutrient cycling will improve. Adding


Photo by Gabe Brown

cover crops to our rotation will increase biodiversity, protect and grow topsoil, pump more carbon into the soil, feed soil biology, and allow the integration of livestock onto cropland. Those who work with nature and follow her principles are seeing an exponential increase in the health and function of their soil, the plants that grow in it, and the animals that thrive on them.

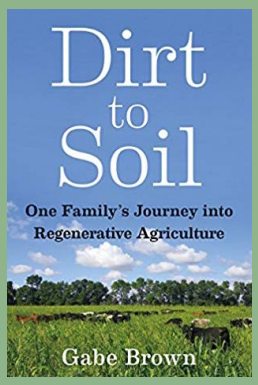
Perhaps the greatest testament to "Regenerative Agriculture" is the fact that it significantly improves not only profitability, but quality of life as well. Those who practice it say that it has made farming and ranching fun again!

Charles Kellogg said it best when he stated, "Essentially, all life depends upon the soil…There can be no life without the soil and no soil without life; they have evolved together."


Photo by Larry Richenburger

By Gabe Brown • Bismarck, ND

Gabe Brown is one of the pioneers of the current soil health movement which focuses on the regeneration of our resources. Gabe, along with his wife, Shelly, and son, Paul, own and operate Brown's Ranch, a diversified 5,000 acre farm and ranch near Bismarck.



To learn more about Regenerative Agriculture, we recommend reading Gabe's book, "Dirt to Soil", where he tells the story of his amazing journey and offers a wealth of innovative solutions to our most pressing and complex contemporary agricultural challenge - restoring the soil.

The Brown's Ranch model, developed over twenty years of experimentation and refinement, focuses on regenerating resources by continuously enhancing the living biology in the soil. Using regenerative agricultural principles, Brown's Ranch has grown several inches of new topsoil in only twenty years!

The 5,000-acre ranch profitably produces a wide variety of cash crops and cover crops, as well as grass-finished beef and lamb, pastured laying hens, broilers, and pastured pork, all marketed directly to consumers.

Keep the Soil Covered

Do you value your soil? If you do and want to improve it, soil cover or armor is essential. Soil cover offers the same protection to soil as a spacesuit does to an astronaut in space. It provides an environment that protects and allows life to flourish even in harsh conditions. Soil cover is an investment that makes soil more resilient during extreme weather events. Drought, flood, heat, and cold can all be buffered by a properly covered soil.

On our dryland Kansas farm/ranch we use cover to feed both our above ground livestock (cattle) and our below ground livestock (microbes). If you are grazing livestock, it is important to leave plenty of residue, not only to armor and protect the soil but also as food for the microbes. Don't be afraid to "waste" grazing material. As the picture shows, residue feeds the soil and then soil feeds the livestock! Soil residue also buffers soil temperatures, keeping them cooler during the summer and warmer in the winter, allowing microbial life to stay alive and working longer.

Photo by Michael Thompson

On our operation we see dry weather more often than not. While it may sound counterintuitive, I look at having something growing and producing cover and residue as an essential part of our strategy to combat drought. I never have found that fallow improved our soil, nor did I get a check for the banking of soil moisture, so I choose to fill my fallow periods with something growing. I am not saying that just seeding random crops is a good idea, but rather be a student of the soil. Dig some holes and see what your soil needs and then plant with a purpose and design a mix of plants that will help improve your soil for future crops.

Good soil cover limits evaporation forces such as the sun and the ever-present wind found here on the Great Plains. You cannot make it rain more during a drought, but you can limit how much moisture leaves your fields from the sun and wind. Good soil cover is like armor, protecting bare soil from sprouting weeds which saves money, time, and moisture. A diverse mix of plants will release root exudates (sugars) into the soil to feed the microbes which are working to create soil aggregation (glues) to keep our soil ready for when we do receive rain.

Photo by Chrisi Lemke Pinto and Jerry Lohners

In the wetter years, soil cover limits the impact of raindrops hitting my soil. It is estimated that raindrops can hit a soil at 90 miles per hour (same impact as hitting it with a sledge hammer). When this happens, small particles of soil are dislodged and plug up the soil pores and prevents water infiltration. Nothing is more heartbreaking to a dryland farmer to see fast-flowing water rushing off fields when rain cannot infiltrate the soil…except maybe the soil loss from erosion that is caused by this! Proper soil cover, coupled with both living and decaying roots, keeps the soil pore space open and allows moisture to be infiltrated deep into the subsoil to be stored for future crops.

Just as an astronaut would never go into space without his protective suit and a knight would never go into battle without their protective armor, you should never farm without the protective cover your soil needs. Soil cover is an investment in the future productivity of your soil resource!

By Michael Thompson • Almena, KS
Thompson Farm & Ranch
Michael is a farmer and rancher in both KS and NE and is a passionate Regenerative Agriculture spokesman. He also serves as president of the Colorado Conservation Tillage Association and is very involved in educating people about Soil Health principles.

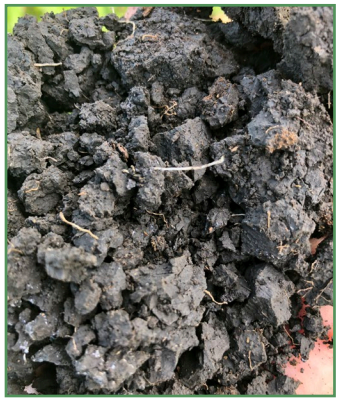
Minimize Soil Disturbance

As a teenager, I remember coming home from football practice, eager to jump in the tractor and run the ripper until the wee hours of the night. That was some of the best times as a junior high and high schooler, being able to help out my dad and run the ripper. I didn't know that there was a different way to have success with the corn on corn we were growing. I thought you had to have the seedbed fully prepared or else it would seal up over the top and the corn wouldn't be able to come through the crusted-over soil. I thought tillage was the answer.

Photos by Mitchell Hora

Now that my soil health journey has taken off, and I've been able to learn from others, I know biology is the answer, not tillage. The ripper is still sitting out behind the shed, where it's been for years, and it won't ever move again (as long as my dad and I are making decisions).

Minimal disturbance is one of the key principles of soil health. In order to build our soils, we must improve the "home" of the microbes and we must increase the biologic diversity in our soils. If we destroy that home via tillage, we destroy that habitat for those crucial microbes. If your house was destroyed year over year, you'd probably relocate, or at least you wouldn't be able to flourish. We see the same thing happen in our soils.



Now that we've adopted no-till across our entire farm, we're seeing those soil structure gains, and we no longer have crusting on our soils. We have good water infiltration, and we don't have near as many weeds getting stirred back up. We're removing our residue via microbe and earthworm activity, which is re-

cycling nutrients and residue for us. Now that we're a couple of years into it, we're having a hard time keeping residue on the soil, and we have had to be more aggressive with carbon inputs from cover crops to feed the system.

It wasn't until we got into cover crops that our no-till systems really started to work. I encourage farmers to adopt more than one of the principles of soil health at a time. It seems that no-till and cover crops go hand-in-hand and will help you have success along your soil health journey.

Other tips for farmers looking to switch to no-till:

- Make sure your planter is tuned in and set correctly, so you get consistent depth and seed-to-soil contact.
- As you upgrade planter or other equipment, don't be afraid to downgrade the size of your tractor or sell your tillage equipment - you'll no longer need it. Remove that temptation from your farmstead and have extra capital in your pocket to make other upgrades to implement a no-till system successfully.
- Start by no-tilling soybeans. We started no-tilling soybeans on our farm in 1986 and have had great success since.

We know that improving soil structure, organic matter, and other soil health components can take a while. But if you are evaluating other agronomic parameters, such as soil biology, improving nutrient flow, reducing weeds, and improving consistency of the crop, then gains can be realized quickly. We have to continue to reduce erosion, improve our impact on carbon in the environment, and implement a no-till or very low disturbance system.

By Mitchell Hora • Washington, IA
Continuum Ag, LLC
For more information, check out Mitchell's website, www.continuumagllc.com or email him at mitchell@continuumagllc.com.

Plant Diversity

A diverse crop rotation system consists of growing different kinds of crops in planned sequences to take advantage of the power of diversity and reduce overall risk. One of the most important roles of a crop rotation is to mimic the natural water and nutrient cycle while maximizing the amount of sunlight captured. Historically, rotations have been much more diverse than they are now and most included phases of perennial crops with livestock integration. This loss of diversity was due to a myriad of economic factors including farm program characteristics; mechanization, development of nitrogen fertilizer sources and pesticides, and specialization in livestock production. Interest in diversifying crop production systems has increased recently. Commodity prices that are low relative to the costs of fertilizer, machinery, labor, and pesticide inputs have led producers to examine means of reducing these costs.

In addition, natural selection pressure resulting from longer histories of tight rotations and monocultures have led to species shifts, resistance, and/or changes in pest's traditional habits that have resulted in yield losses. Proper application of rotational planning can increase yields, reduce costs, and improve soil health and fertility. These positive benefits affect whole farm economics by reducing weed, disease, and insect pressure and resistance; spreading workloads to reduce fixed machinery and labor costs; providing more optimum planting and harvesting timing; and diversifying income and spreading weather risks. Failing to match natural systems has caused much of the environmental issues we face in US agriculture.

Photo by Doug Steffen

When diversity cannot be easily added to the cash crop rotation, consider adding it through a diverse multi-species cover crop mix. This mix of vetch, peas, cowpeas, barley, oats, millet, sorghum, brassicas, buckwheat and sunflowers does just that!

It is over-simplistic to classify rotations as good or bad, but rather rotations have differing characteristics in terms of their impacts on various aspects of the crop production system used. Designing appropriate rotations is a mix of art and science. Since all aspects (agronomic, environmental, economic, engineering) must be considered simultaneously, a systems approach is required. For any given situation, there will be a range of rotations that will be appropriate and within this range rotations will have differing characteristics in terms of the risk they pose, which may make some more suitable for use in a particular location. Management decisions must be made by individual producers to select the rotation or combination of rotations that is most appropriate for them.

By Dwayne Beck, Ph. D • Pierre, SD

Dwayne Beck has had more impact and influence on Plains Agriculture in this generation than anyone else we know. As director of the Dakota Lakes Research Farm in Pierre, SD, Dr. Beck has developed his vision of regenerative agriculture in the field and not in a laboratory or a classroom. His practical approach to systems based agriculture is legendary and his candid style of education is refreshing to anyone who has heard him speak.

Beck's "Rotation Rules"

- *Reduced and no-till systems favor the inclusion of alternative crops. Tilled systems may not.*
- *A two-season interval between growing a given crop or crop type is preferred. Some broadleaf crops require more time.*
- *Chemical fallow is not as effective at breaking weed, disease, and insect cycles as are black fallow, cover crop, or production of a properly chosen crop.*
- *Rotations should be sequenced to make it easy to prevent volunteer plants of the previous crop from becoming a weed problem.*
- *Producers with livestock enterprises find it less difficult to introduce diversity into rotations.*
- *Use of forage or flexible forage/grain crops and cover crops enhance the ability to tailor rotational intensity.*
- *Livestock make using rotations with perennial sequences easy. It is probably not possible to be sustainable over long periods of time without using perennial plants in the system.*
- *Crops destined for direct human food use pose the highest risk and offer the highest potential returns.*
- *The desire to increase diversity and intensity needs to be balanced with profitability.*
- *Soil moisture storage is affected by surface residue amounts, inter-crop period, snow catch ability of stubble, rooting depth characteristics, soil characteristics, precipitation patterns, and other factors.*
- *Seedbed conditions at the desired seeding time can be controlled through use of crops with differing characteristics in regard to residue color, level, distribution, and architecture.*
- *Rotations that are not consistent in either crop sequence or crop interval guard against pest species shifts and minimize the probability of developing resistant, tolerant, or adapted pest species.*

Living Roots as Often as Possible

The past 150 years of conventional farming has been very extractive and destructive to our soils, with extensive loss of both topsoil and soil organic matter. To be able to regenerate our soils, we must first identify what our resource goals are for that field. It might be to build more carbon, reduce erosion, increase infiltration rates, supplement livestock feed, cycle nutrients, provide a nitrogen source for the next crop, increase mycorrhizal fungi, etc… Whatever that resource concern is, it must be addressed with a living root that will feed the soil microbes through carbon-rich root exudates.

Photo by Jimmy Emmons

Plant root exudates leaking out to feed soil biology.

However, when crop rotations consist of only annual monocultures, the soil and the microbes are only being fed for 3-4 months out of the year. Limited living roots and very little diversity leads to a minimal amount of biological activity and diversity, which causes our soils to be weak and anemic. Living roots "trade" or "sell" their carbon-rich root exudates to soil microbes in exchange for plant nutrients that are being made available through biological processes. This basic economy forms stable soil aggregate structures that increase soil infiltration and water holding capacity as well as create a habitat for the microbes to live on as they move around in films of water in the soil. Improved soil structure also aids in the soil's inhalation of oxygen which is critical for microbes to survive.

Oxygen, food, water, and shelter: things that all living creatures, including soil microbes, need to survive. Healthy soils can provide all of these but it all starts with living plant roots! Cover crops are essential in this cycle of life as they maintain a carbon flow in the "off season" of our cash crops. The more diverse and complex the cover crops are, the more diverse root exudates are produced, feeding more of a diverse community of microbes in the soil. More is better than less but something is better than nothing, so don't be afraid to plant a very basic cover crop like cereal rye if it is late in the growing season and that is the only thing that makes sense to use – it will still give a great carbon boost to the soil's biological life!

Photo by David Kleinschmidt

Many farmers are finding new ways to work with nature and the complexity of plant collaboration by interseeding cover crops into standing cash crops. These cover crops are designed to not compete with the cash crop but they act as a trade-off of nutrients as the mycorrhizal hyphae connect to different plant species. As one plant is naturally senescing, the next cover crop is right there to take off and keep the carbon pump primed and to keep the nutrients cycling. This "Catch and Release" method, as Jeremy Wilson refers to it, ensures that the nutrients mineralized from one crop are taken up and made available to the next crop, part of the nutrient cycle. This helps to ensure that nutrients stay on the fields they are in and out of the watersheds where they can become a toxic problem to many communities downstream who rely on that water source for municipalities and fishing industries.

Photo by Brett Peshek

By David Kleinschmidt • Mulberry Grove, IL

David Kleinschmidt is an Independent Soil Health Crop Consultant from Illinois as well as a contract consultant with Understanding Ag, LLC.

Livestock Integration

As with any agricultural enterprise, the health of our soil is paramount to our success. Integrating livestock is often either completely overlooked as an option for farming operations or undervalued as a tool in livestock operations. The opportunity exists to take advantage of grazing management as a tool to increase ecological function while providing positive economic returns.

Whether we are focused on integrating livestock into a cover crop system on cropland or a native rangeland ecosystem, managing the grazing by properly integrating livestock can have significant impacts on the health of our soil resource. Properly integrated livestock can aid in nutrient cycling, as up to 85% of the nutrients consumed during the grazing process are returned to the field in the form of manure and urine. Those nutrients are then distributed across the field by managing paddock access through rotational grazing management strategies. These strategies are governed by managing four core tenants of grazing; the timing, intensity, frequency, and duration of the grazing event.

Photo by Brett Peshek

Timing refers to "when" to graze. Specifically, when to begin and when to stop grazing. When to start grazing differs with the forage type and seasonality. In general, begin grazing when enough forage growth has occurred to meet target demand and allow adequate plant recovery. Stop grazing when approximately half by weight of the target species has been removed. Timing also refers to seasonality. In perennial systems, adjust the rotation so that pastures are grazed at different times in subsequent years.

Intensity refers to "how much" to graze. Most forage species produce double what they need to sustain themselves. Hence, 50% of the top growth can be grazed without hindering root development. In general, focus should be placed on the half of the plant remaining following the grazing event. Managing to leave 50% allows the plant adequate photosynthetic material to recover. This amount will differ given the forage type.

Frequency refers to "how often" to graze. Frequency determines the grazing recovery period. In general, recovery periods should be long enough to allow the forage to fully recover before being grazed again. Recovery periods are typically shorter during periods of fast growth and longer when forage growth slows down. Adequate recovery periods are often the factor that drives success or failure in rotational grazing systems.

Duration refers to "how long" to graze. Duration is in reference to the actual grazing period. The grazing period length depends on the tenants listed above and is largely driven by time. Overgrazing is a function of time, not intensity. The grazing period should be timed to limit livestock from grazing the same plant twice. If livestock have access to plants for "too long", they will graze them twice during the same grazing period limiting recovery.

Given a proper overall ranch stocking rate, a tool often overlooked is stock density. Stock density is the number of animals on a specific area and can be used as a tool to meet multiple ecological outcomes while providing positive economic returns. Managing stock density allows the grazing manager the freedom to balance the timing, intensity, frequency, and duration of grazing on any forage type and ultimately provide positive soil health returns.

By Jeff Goodwin • Ardmore, OK
Noble Research Institute Conservation Stewardship Leader, and Pasture and Range Consultant.

Ecology is the science of interconnected relationships between organisms and their environments. One of the most ecologically influential organisms on our environment is plants. Without plants, life could not exist on Earth as plants impact all four of the critical ecosystem processes that sustain life. In fact, one of the biggest mistakes of soil science is teaching that plants and soil are separate ecosystems, when in reality, they are the same ecosystem. Without plants you cannot call soil soil — which by definition, denotes life! Soil without plant and microbial life is just geology – dirt and rocks! Soil is the intimate union between biology and geology. Plant-soil life is the most powerful geological force on the planet and without it, these four life sustaining ecosystem processes would not happen and earth would be a lifeless planet.

Photo by Lance Klessig

If farmers, ranchers, and agriculturists are going to make a sustainable living on the land, it is critically important to understand how the four ecosystem processes function and how critical plants are to these systems. These four processes provide daily services that are critical to all of life on the farm, ranch, and other natural ecosystems, and indeed it is not an overstatement to say that all life on earth depends on these keystone cycles. These four processes are interconnected and cannot function properly without each other. If one of these processes is missing or compromised, then the other processes will not function properly, which will diminish ecosystem services and reduce our ability to produce feed, fiber, and food for a growing world.

> *"Soil without plant and microbial life is just geology - dirt and rocks! Soil is the intimate union between biology and geology."*

1. Capture Solar Energy

Plants capture the sun's energy through photosynthesis and convert this light energy into chemical energy which is then transformed into carbon-based molecules which nourish and sustain almost all living organisms on the planet. $6CO_2+6H_2O = C_6H_{12}O_6 +6O_2$ is the most important piece of chemistry in the world! The simple carbon sugar glucose molecule formed in photosynthesis is the basis for our entire food chain… and having breathable oxygen as a byproduct is not bad either! Ancient people used to call plants "the mouth" of the soil, because without plants the soil does not eat. Plants are the primary conduits of life-sustaining energy which is used to feed the biological life in the soil, which in turn feeds us!

2. Nutrient Cycling

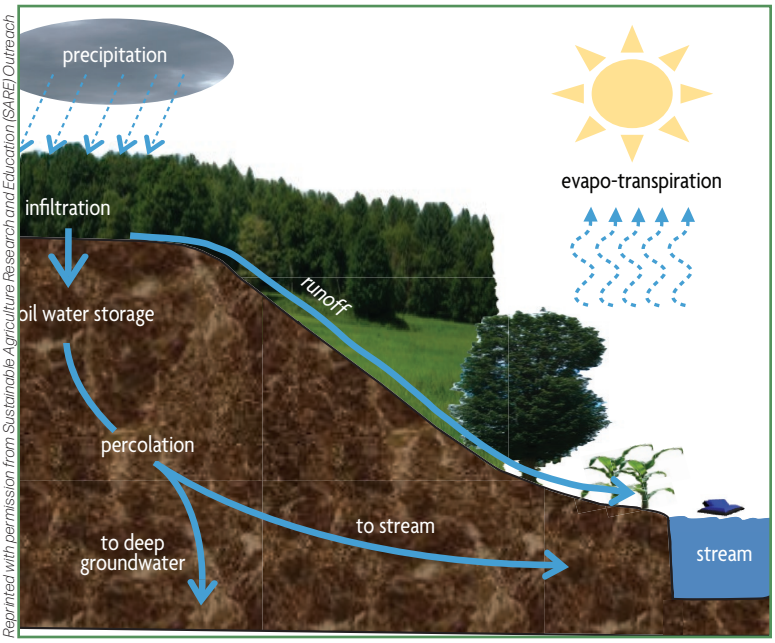
This process occurs when plants exude their myriad of photosynthetically derived carbon-based molecules through their root systems to feed a plethora of soil organisms. In return, this soil biota community mines, extracts, modifies, and delivers nutrients and minerals from the soil matrix and "trades" it back to the plant in exchange for carbon-based food. Additionally, microbes (rhizobia and others) can convert inert atmospheric nitrogen into plant available nitrogen that allows a plant community to grow and thrive. Plants and microbes are responsible for over 90% of natural nutrient cycling, availability, and production for living organisms.

3. Water Cycle

As plants and microbes collaboratively modify their mineral habitat, they create super biotic glues that aggregate sand, silt, and clays to create a porous structure which allows the infiltration of water. Infiltration is the key to the water cycle and its importance cannot be overstated. Plants also increase infiltration through root channels and protection from the kinetic energy of rain drops. The amount of rainfall a farm receives is irrelevant if the rain does not infiltrate into the soil. Many droughts are partially the result of poor infiltration. Additionally, plant evapotranspiration is a key part of the water cycle as 40% of our inland rain comes from plants and soil creating humidity.

4. Community Dynamics Through Biodiversity

Diversity of plants, insects, microbes, and other organisms are responsible for transporting energy, nutrients, and mass from one organism to another. Biodiversity is the foundational ecosystem service to which our human well-being is intimately linked. No feature of Earth is more complex, dynamic, and diverse than the biosphere, the layer of living organisms that occupy our soil surface and chemically unites the atmosphere, geosphere, and hydrosphere into one environmental ecosystem within which millions of species, including humans, have thrived. Diversity is a conduit or a transport mechanism to all living organisms on the planet. Plants create an architecture of habitat and biodiversity facilitates the self-healing, self-regulating, and self-organizing mechanisms for all natural ecosystems. Diversity creates health and resilience in biological systems and without diversity of plant life, it is impossible to achieve diverse soil life.



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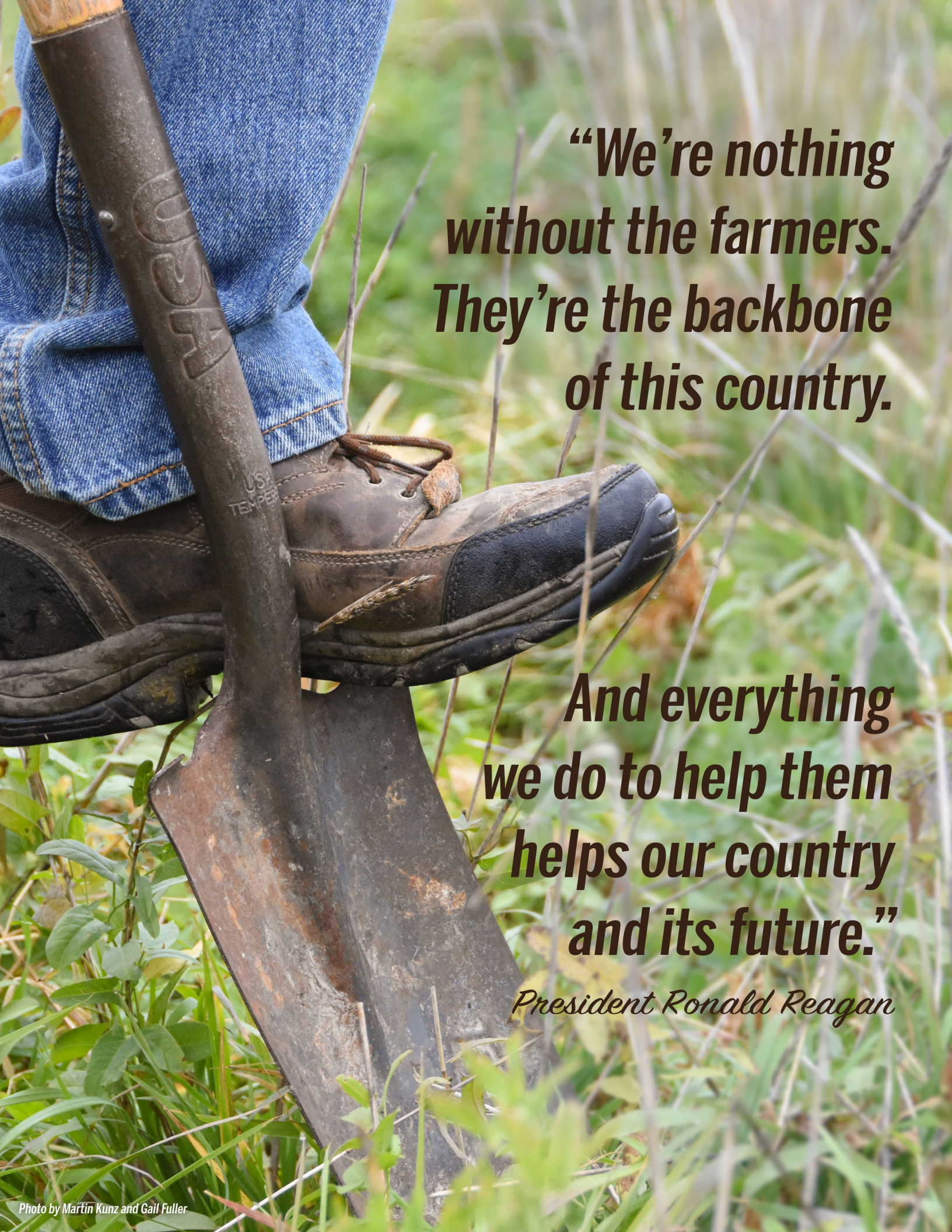
It is important to understand that financial stability can only be accomplished through ecological viability. Simply said, "grow more green plants, if you want to be in the black". Growing more plants will require cover crops. Our farms/ranches must run on new sunlight (capturing solar energy with plants) not on ancient sunlight (petroleum-based inputs). Planting diverse cover crops are not optional as these plant communities facilitate life! The more you feed your soils with diverse plant communities, the more ecosystem services the soil will provide, including nutrient cycling, healthy plants/animals/humans, resilience against drought with increased water holding capacity, less erosion, reduced flooding, stabilized climate, decreased pest pressure, and reduced pesticide usage. These are but a few of the rewards for investing in systems that leverage the power of ecosystem services.

Photo by Brendon Rockey

By Ray Archuleta • Seymour, MO

Ray Archuleta is one of our all-time favorite "soil guys". He is a Certified Professional Soil Scientist with the Soil Science Society of America and has over 30 years experience as a Soil Conservationist, Water Quality Specialist, and Conservation Agronomist with the Natural Resources Conservation Service (NRCS). During his tenure with the NRCS, Ray served in New Mexico, Missouri, Oregon, and North Carolina. After his retirement from the NRCS in 2017, Ray founded Understanding Ag, LLC, and Soil Health Academy, LLC, to teach Biomimicry strategies and Agroecology principles for improving soil function on a national scale. Ray also owns and operates a 150-acre farm near Seymour, Missouri that he operates along with his wife and family. To learn more, please visit Ray's website: www.understandingag.com.



"We're nothing without the farmers. They're the backbone of this country.

And everything we do to help them helps our country and its future."

President Ronald Reagan

Photo by Martin Kunz and Gail Fuller

Interseeding

Since many farmers struggle to incorporate diversity into their crop rotation, some are looking to add diversity by growing cover crops within their cash crop. Before pre-emergence herbicides, it was common to seed cowpeas, clovers, or other crops in between rows of corn to gain an additional crop in the season at "layby" time. Modern experimentation with this interseeding concept has been going on for the last several years, but this technique is still in its infancy and successful interseeding has a number of challenges to overcome.

Stand Establishment

No crop can ever be better than the initial stand that is achieved. For interseeding into growing corn fields, getting the seed in the ground always outperforms broadcasting. Companies like Hiniker, Dawn, and Interseeder Technologies have developed equipment just for this purpose.

Lack of Sunlight

Interseeded companions always struggle to get enough sunlight. Best results have occurred when covers are interseeded at V3-V6 and a stand gets established before the corn canopies. Once a plant is established it can survive better in partial shade. Corn varieties with more upright leaf structure can also help. This practice tends to work better as you move north where the summer days are longer (more hours of sunlight) and the maturity of the corn tends to be shorter. Some innovators are also experimenting with wider row corn while not sacrificing plant population.

Herbicides and Weed Control

If planting a diverse mix of covers (grasses and broadleaf), most post-applied herbicides will not work without hurting the companion crop. Penn State research shows that some pre-plant applied short residual herbicides like Resolve, Prowl, Sharpen, and Verdict may work with companion interseeding. Do not try interseeding in fields where you know you have difficult weed issues that will require post-applied herbicides.

Crop Insurance

Because intercropping into growing corn is a relatively new practice, there are some gray areas of interpretation when it comes to crop insurance. The guidelines can vary from zone to zone so it is best to always check with your crop insurance agent. The bottom line is that insurance will not cover loss of production resulting from cover crop interference with the agronomic management and harvest of the main crop. With interseeding into corn that is at V4 or later maturity, we are not aware of any studies that show the companion is a threat to the cash crop.

Left Photo by Jeremy Wilson • Right Photo by Dean Krull

Left: Jeremy Wilson seeded this 14-way blend into V6 corn in Jamestown, ND using a modified Yetter dry fertilizer coulter. Great stand establishment, excellent growth, and lots of diversity. Picture was taken when corn was fully tasseled. Cost of seed mix was around $12 per acre as rates were calculated for intercropping.

Right: Ken Seims and sons of Chapman, NE planted this blend of ryegrass, red clover, and radish into irrigated corn at V6 with a Hiniker cover crop seeding system. Good stand but growth is being suppressed by lack of sunlight, but wait till harvest and watch it take off!

The methods employed by producers to achieve successful interseeding are as varied as the producers themselves. If you are interested, we encourage you to experiment on a small scale, but proceed with caution and check with your crop insurance agent to maintain compliance. For a great on-line resource on this topic, go to www.interseedingcovers.com.

Photos by Lowell King

Above: Lowell King of Fruita, CO is using his Interseeder drill to place three rows of companions between each row of V4 corn.

Below: Here is what the companions look like late in the season - and this is especially impressive as this is a gravity irrigated field!

Relay Cropping

As ag producers, we should always be looking for ways to use our assets (land, equipment, and time) more efficiently and increase profits while protecting the environment. Relay cropping is one way that a growing number of innovative growers are doing this. Relay cropping is essentially a version of double cropping, where the second crop is planted while the first crop is still growing, rather than waiting until after harvest. Both crops share a portion of the prime growing season, increasing solar radiation and heat available to each and allowing two crops in one year on more northern regions. Loran Steinlage from West Union, IA is one of the leading proponents of this movement and writes here about his experiences:

In 2013, I was getting very comfortable with innerseeding* covers into V4 corn and started thinking of how these principles could translate to the rest of our rotation? I wanted to bring a small grain back to my rotation, but in my area of high land rent I knew that wheat alone would not pay the bills and we are too far north to double crop. As I was researching, I found other innovators both doing wheat and soybeans in a "relay cropping" system.

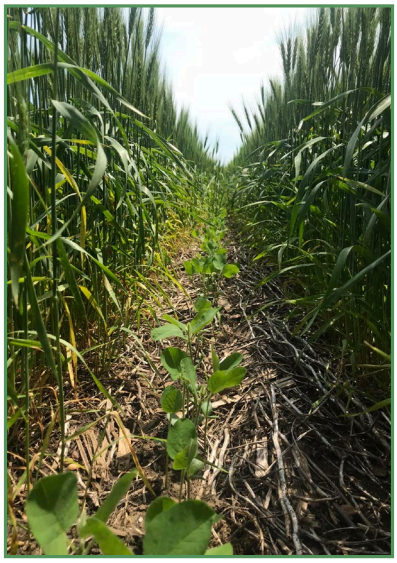
Photos by Loran Steinlage

I started with small plots and began focusing on the equipment side and quickly realized the equipment I was using for innerseeding would work for planting the relay wheat and soybeans. We liked what we saw and scaled up quickly because once we understood the basics, it just made sense. Then we had the crazy idea to drill buckwheat where the cereal was and it provides us with weed control and an easy companion to the soybeans. We harvest the soybeans and buckwheat together and separate them with a grain cleaner.

One of the biggest advantages during the last couple of wet years is that the cereals tend to help the beans through the early wet periods. Our relay soybeans have been our highest yielding beans the last three years running! We are now trying spring malt barley and spring oats which have advantages when the previous fall was so wet or late that we could not establish a winter cereal.

For harvesting, we bought a row crop head so we do as little damage as possible to the soy during cereal harvest. We are either going for seed quality or food grade on most crops, so the consistency and lack of damage is critical from seeding to harvest on crops. With the relay cropping system we are able to consistently grow food grade wheat without fungicide in Iowa – something we were told wasn't possible when we started growing cereals.

Over the years, we've learned what diversity of plant species can do for us. Innerseeding and cover crops boost beneficial organisms which eat the bad organisms, and diversity of plants growing together (covers or relay crops) actually confuse a pest's sense of sight and smell. If we can maintain a residue cover with minimal soil disturbance, we will not have weeds, either; bare dirt equals weeds in our world. Our soils have aggregation like you wouldn't believe. We have textbook healthy soil – it looks like coffee grounds or black cottage cheese, and each shovelful contains 16 to 20 earthworms. We are at the upper levels of the microbial respiration soil tests and infiltration tests on our farm showed 1" of water penetration in eight seconds.



** Loran found research from the 1900's on the concept of "innerseeding" ("interseeding") so he honors that spelling out of respect to our forefathers.*

By Loran Steinlage • West Union, IA
You can follow Loran Steinlage and FloLo Farms on Twitter.

Poly Cropping

You don't have to reinvent the wheel when it comes to regenerative agriculture, but you may have to dig deep into agriculture archives to find the next big idea. After listening to Derek Axten speak at the No-Till On The Plains Winter Conference about growing companion crops, Haxtun, CO farmer John Heerman researched companion cropping options and found there were several key points to consider:

Do Your Research: Like most regenerative farmers Heerman doesn't believe everything he hears, and is thoughtful about making big changes. After hearing Axten, a Canadian farmer, speak about companion crops Heerman did more research. He found a plethora of recent information on companion crops in Canada and from the 1920s and 1930s in Nebraska. You must analyze the data, but even old information can still hold valuable knowledge. You don't have to take huge risks. Heerman advises research to, "Find something that is proven and cleanable."

Manage for the Primary Crop: Heerman's companion crop of rye/Austrian peas was managed with the rye as the primary crop and the Austrian pea as the auxiliary crop. The Austrian peas were a new market in the area, but Heerman already had established markets for the rye. He approached the companion crop as a way to increase diversity and farm profits; however, he wasn't willing to sacrifice the main crop. He found the Austrian peas created no yield drag compared to his monoculture rye fields; all the Austrian peas became a second income stream on the rye companion acres. Likewise he manages his chickpeas as the main crop and the flax becomes the extra income from those acres.

Photos by John Heerman

Easy Separation: In order to capitalize on the second income from the same acres, crops must be separated. All Heerman's companion crops include different size seeds so they can be separated using a basic seed cleaner. Heerman suggests taking a handful of the companion crop seeds and mixing them together then separate them out to see how easy or hard it will be. The larger the seed size discrepancy is, the easier it will be to separate the seed.

Utilize Your Current Equipment: Growing a companion with your primary crop needs to be easy and not cost you much in capital investments. Heerman plants his companions in the same row, putting different seeds in his air cart compartments. Then he uses his Shelbourne-Reynolds stripper header to harvest his companion crops. With many pea varieties, harvesting monocultures can prove to be a challenge because the peas are so close to the ground, but Heerman has found that the rye gives Austrian peas something to vine up, keeping them off the ground and making them easier and faster to harvest. In 2019 he was able to harvest his companion crop peas at 6 MPH vs. monoculture peas at 1.5 MPH.

Consider Herbicide Options: When planting companion crops you must manage herbicide labels. Heerman said he liked stacking chickpeas/flax because you can find grass herbicides labeled for both giving you more options. With rye/flax or rye/Austrian peas companion crops you don't have any herbicide options post-emergence. He noted that the rye crops usually do a good job of keeping fields clean, so he is not concerned about the lack of post-emergence herbicides.

As with any rotation you must keep the whole system in mind. In Heerman's semi-arid environment, managing for carbon in the system is important. Five years ago, he eliminated fallow on his farm. His fall planted crops consist of rye companion planted into chickpea and flax companions or covers. He likes the increase in residue the flax brings to the chickpeas, decreasing the chance of bare soils. His companions have also increased diversity and decreased pest problems in his cash crops. Heerman has also cut out fertilizer on crops that are primarily legume crops and accounts for residual nutrients from those legumes in the following rye crops. By continuous cropping rye behind the chickpea companions or covers, Heerman basically has no fallow expenses. He converted months that were a significant expense into an income producing crop. "I have basically $0 to get back to my next rye crop," Heerman states.

There are resources available to help you decide what is the best decision on your farm. Talking to those who have had success and failures with the practice can teach you valuable lessons. Expanding your network and being in the position to hear those other producers is key. Then, do your own research and make your decisions.

Cover Crops - The New "Weed And Feed"

Lessons From Organic Farmers That We Can All Learn From

Only a small percentage of our customers are certified organic, and for a good reason: it isn't easy. The two primary challenges are weed control and providing mineral fertility. True, there are ways to control weeds (manual pulling) and ways to provide soil fertility (blood meal for nitrogen, bone meal for phosphorus, greensand dust for potassium), but the problem is that these methods are also incredibly expensive and often not practical at scale. Another drawback is that many organic farmers rely on tillage as a means of weed control, and we all know how destructive tillage is to soil quality.

However, we know of some innovative organic farmers who are developing means to control weeds without tillage or herbicides and providing nitrogen fertility without expensive purchased organic fertilizers. The key to both practices is the intelligent use of cover crops. One of these innovators is Dan Desutter of Attica, IN, who was a long time no-till farmer and cover cropper who decided to jump into organic farming. His experience with using cover crops to control weeds and fix nitrogen gave him the confidence that he could successfully make the jump to organic crop production.

Dan extended his rotation beyond the typical corn-soybean rotation in his area to include wheat. Following wheat harvest, a multispecies cover crop mix that includes summer annual legumes like sunn hemp and cowpeas is planted for livestock grazing. After grazing, a winter mix is planted that includes some species that winter kill, along with a legume that overwinters, such as FIXatioN balansa clover. This winter legume is then terminated with a roller crimper in late May, and the resulting thick mulch provides a barrier to weed seedling emergence as well as a slow release nitrogen source.

In late May of 2019, Dan measured the nitrogen content of his balansa clover mulch and found it contained a whopping 350 pounds of total nitrogen! Even when figuring that only half of this nitrogen might be available to the following crop (soil microbes always sit at the table first, plants get the table scraps) this amount can fulfill the nitrogen needs of a very high yielding corn crop, especially when combined with the nitrogen produced by the decay of the previous summers cover crop and the manure and urine left over from the grazing.

Photos by Dan Desutter

After corn harvest, a cover crop mix based around cereal rye is used to sequester left over nitrogen, creating an environment that is low in plant available nitrogen. The soybeans are planted into the standing rye which is then roller crimped at V2.

Both corn and soybeans are planted in 30-inch rows, so if any follow up weed control is needed it can be provided by one of two methods. The first is the use of a "row-mow" – a device similar to a row-crop cultivator, but with the cultivator shovels replaced with a rotary mowing device that cuts any weeds off just above the soil surface and turns the weeds into a nitrogen-releasing mulch. The second option used to control weeds that grow above the soybeans is an electric weed zapper. This device uses high voltage electric terminals that are mounted on either side of the crop row and immediately above the crop. Any weeds that are poking above the crop complete the circuit between the positive and negative terminals and are literally fried. Not only is this an effective weed control method, it is also great entertainment! Dan says that his corn grown in the cover crop mulch and all the decaying organic matter from previous crops and cover crops is healthier and more vibrant than his corn crops in the past.

Another farm which uses cover crops for both nitrogen and fertility management is JNG LLC, a certified organic farm operated by Jerry Lahners of Hebron, NE. JNG is primarily in a corn-soybean rotation, a rotation in which most people have difficulty working in viable cover crops. At JNG, cereal rye is drilled after corn harvest. In the spring, soybeans are planted into live rye when the rye is nearing pollination stage. Once the rye reaches pollination stage, the rye is roller crimped down to flatten the mulch and allow the developing beans to reach sunlight. Jerry feels that delaying the roller crimping until after the beans emerge allows the rye to pump more root exudates into the ground and provide more benefit to soil microbiology. The rye in a normal year with a good thick stand provides very good weed control, because it sucks up any nitrogen left over from the previous corn crop and stores it in weed-suppressing residue, and out of the reach of weed roots. Once the soybeans reach leaf yellowing stage, hairy vetch is aerial seeded into the standing soybeans and the pivot is used to water them up as well. In the spring, corn is planted into hairy vetch that is rolled down after it begins blooming. This means that planting is a bit later than normal for the area, but yields are still ordinarily very good. The corn in the photos planted into hairy vetch mulch made 185 bushels per acre. While that won't win you many coffee shop bragging contests, remember this crop was produced with untreated non-GMO seed, no insecticide, no herbicide, no fungicide, no tillage, and no fertilizer, and then sold at organic prices (around $9 a bushel).

Other acres include wheat in the rotation followed by cover crops that are grazed to further build soil. Next, a hairy vetch cover crop will be seeded around Labor Day to produce nitrogen for next year's corn crop Jerry is quick to caution people that they will likely not achieve these yield levels after a single year of cover crops without added nitrogen and in the early years he used chicken litter to supplement his nitrogen needs. However, after several cycles with cover crops the pool of mineralizable nitrogen builds up and can eventually provide good yields without the need for imported nitrogen. While Jerry relies on these practices primarily because he is certified organic, he also points out that these same practices can also be used with equal benefit by farmers who are not organic. There is no reason that a farmer could not supplement the nitrogen from the hairy vetch with a little additional nitrogen, or some phosphate or potash, but be able to dramatically reduce their need for nitrogen. Additionally, a farmer could supplement the mulch with a herbicide application, or use a chemical burndown rather than a roller crimper, but use the weed control benefits of the residue to reduce herbicide rates or applications. Jerry also points out the obvious benefit this system has to other organic farmers, in that he has nearly eliminated tillage from his operation, and still manages to do a very good job of weed control. The success that Jerry has had demonstrates that tillage is NOT a necessary component of organic farming, that there are other means to control weeds. But while Jerry is happy with his results, he is far from satisfied. He thinks we are just scratching the surface of what we can do in eliminating both tillage and synthetic inputs from cropping, and that there are lessons to be learned in that pursuit that can benefit both organic and non- organic farmers alike.

Photos by Jerry Lahners

Crimping hairy vetch and planting organic corn all in one pass, Jerry Lahners is taking care of the entire weed control and fertility program for this crop all at once! Just add water and watch it grow!

Double Crop Companion Flowers

We all know that diverse and long crop rotations are more agronomically sound than short rotations with few crops (see Dwayne Beck's article on page 9). Despite this fact, many farmers have moved away from longer rotations that include cereal grains, partially due the current low profitability of wheat. This is unfortunate because summer harvested crops provide the window to plant a diverse cover crop that includes rapid growing summer annuals for tremendous soil improvement in a short period of time, and generate additional income from grazing. But farmers without livestock may lack the ability to convert a cover crop directly to profit so growing cash crops rather than a grazing crop is often very important to financial well-being of the operation. This has led to following small grain harvest with double crop soybeans or eliminating the small grain year altogether, as double crop soybeans are often not feasible or marginally profitable and they offer very limited soil benefits compared to a diverse cover crop.

Photos by Joe Swanson

One creative alternative is to follow small grain harvest with double crop sunflowers and have an underseeding of cover crops to create soil benefits. The sunflowers and the cover crops can be mixed together and seeded at the same time or a more precise placement of the sunflower seed with a corn planter may help it yield better, but this requires a second pass with a drill to seed the covers. Since only the top of the sunflower plant is harvested, the cover crop can be left standing in the field after harvest.

The companion covers should be selected to not impede the harvest of the flower as well as adding benefits to the system. For example, legumes like cowpeas, mung beans, crimson clover, spring peas, or hairy vetch can be included to host nitrogen fixing bacteria. Buckwheat and mustards can be used to produce copious amounts of aromatic nectar that will mask the sunflower aroma from sunflower head moths, feed beneficial pollinators and honeybees, and also attract lady bugs and lacewings that can help control many other insect pests. Grasses like oats or annual ryegrass can provide soil protection from erosion and soil aggregating root exudates. The remaining cover crop biomass can all be grazed after harvest, providing an additional income stream for those able to capitalize on it.

One farmer that has utilized this double crop sunflower plus cover crops concept to good advantage is Joe Swanson of Windom, KS. In 2019, Joe planted sunflowers along with a companion crop blend that included mung beans, buckwheat, watermelons, pumpkins, crimson clover, flax, mustard, and rapeseed. This mix was planted at the same time with Mycogen sunflowers with an airseeder, all in the same rows together, but with sunflowers in one box and the cover crop blend in another. Stand establishment and growth of flowers and covers was spectacular, but the sunflower yield was disappointing, perhaps due to an infestation of stem borers. The pumpkins and watermelons produced exceptionally well and provided opportunities for "pick your own" projects with local youth groups. (Note: be sure to clear any harvesting of fruits and vegetables and selling for profit with your FSA office). According to Joe, the best result of this project was the soil health benefits, which will not become readily apparent until he sees how well future crops do. But as Joe says, "All that diversity and biomass have to be helping the soil. Although the sunflower yield was disappointing, we are glad we tried this and we plan to continue to experiment with the mixtures going forward. It was a fun project, and not just to us but the entire neighborhood. If I had a dollar for every person who stopped and took a picture, I would have made more money from photos than I did on the crop!"

Growing Hemp Using No-Till and Cover Crops

I've been interested in growing hemp since I attended a meeting back in 1999 regarding its many uses. When it was legalized in my state of Pennsylvania, I dove right in! Not only growing this new—yet very old—crop but doing so using cover crops and no-till. Unlike other cash crops, hemp is quick growing and mostly disease and insect resistant, so I believe we can all but eliminate many of the inputs typically used.

Year 1

Since my whole farm was planted in cover crops anyway, I had a good start. The various cover crop mixes were sprayed with a pint of glyphosate and roller crimped, starting the end of May and finishing up the middle of June—the prime-time CBD hemp planting season.

I then planted a mix of clovers (Dutch White, Aberlasting, and Red) and some low growing perennial grasses like they use for "the rough" in golf courses. The intention was to keep something growing in the soil and provide both weed control and N production from the clovers. Most importantly the cover crops needed to be low growing so as not to interfere with the CBD hemp which is planted in a 5 ft by 5 ft spacing. These 23 acres were then no-till transplanted using my vegetable transplanter that I built in the late 90's.

Photos by Steve Groff

We then mowed those fields three times using a small walk-behind sickle bar mower to control weeds and to keep the low growing cover crops to a short height. We did have an acre where we applied no glyphosate and discovered that we didn't need that application. Each time we mowed, we followed up with hand hoeing to get any weeds that were directly on the row. One key observation was where hairy vetch was a part of the cover crop mix, the CBD hemp was the best! The remaining 47 acres was direct seeded using our 30" Kinze no-till corn planter. It is set up with Precision Planting meters. We used sugar beet seed discs and glued every other hole shut to get the lower seeding rate needed. This was planted after small grain harvest where the straw had been baled. As we expected, weed control was lacking and there are not any herbicides labeled for hemp. Those fields were weedy and did not amount to much!

What We Will Do Different in 2020

In preparation for the upcoming year, we have increased the percentage of hairy vetch for fields where we plan to plant hemp. I believe we can all but eliminate nitrogen and herbicides. I still want to try direct seeding, but into a heavy cover crop this year as we need that for weed control. I'd like to develop a mower that will be tractor mounted and cut between multiple rows at a time.

I believe hemp holds promise to help farmers now in the weak economic cycle that most of agriculture is currently in. But there are dangers associated with a new industry that is literally forming before our eyes. Learn all you can. Start small. Be wise in who you deal with in selling the crop.

I have launched an educational endeavor that brings interested growers together where we can ask and answer questions regarding growing this crop that is new to most of us. Learn more about Hemp Innovators by going to: www.hempInnovators.com.

Steve Groff's HEMP INNOVATORS

By Steve Groff • Holtwood, PA

Steve Groff is a research-based farmer, agricultural consultant, speaker & author based in Lancaster County PA. He has 25 years of experience in cover crop research and has deep roots in studying cover crops and hemp planting.

Interseeding into Cool Season Perennials

Cool season perennial grasses such as brome, bluegrass, orchardgrass, and fescue require a great deal of nitrogen fertility for optimum growth and usually grow very little during the heat of summer. These factors have led some people to experiment with drilling or broadcasting other crops into these grasses to increase forage production or fix nitrogen with interseeded legumes. Drilling spring peas, lentils, or chickling vetch in either fall or early spring can provide both additional forage and nitrogen fixation as soon as 60 days after planting, though these species are short-lived. Broadcasting or drilling a blend of red clover, ladino clover, annual lespedeza, chicory, and plantain in either late summer or winter can extend the grazing season further into summer, as well as provide all the nitrogen needs of the stand. This blend takes a while to begin production, but the plants persist for many years. Doing both practices at the same time can provide excellent initial production along with long term benefits. Teff grass or improved varieties of crabgrass can also be broadcast in spring to increase summer production. Crabgrass is very high quality and productive and reseeds itself well if not overgrazed.

Other innovators have discovered that they can graze cool season pastures down in the late spring, then drill a blend of warm season cover crops such as sorghum-sudangrass, BMR grazing corn, pearl millet, cowpeas, okra, and sunn hemp for grazing in late summer for an incredibly high yielding pasture. This strategy can either provide better summer pasture, or provide growth that can be stockpiled over summer to add to fall grazing. One eastern Kansas farmer has recorded yields of over eight tons per acre of cover crop dry matter on this system, all produced after a late June grazing of his fescue-clover pasture. He has done this for four years running and his fescue looks better than ever, far better than that of his neighbors.

Photos by Dale Strickler

Hidden treasures, like this pumpkin, are found in the understory of a diverse mix. Vine crops like pumpkins, melons and squash grow very well in cover crop mixtures and are highly nutritious and readily consumed by livestock.

Interseeding into a perennial stand is always challenging. For the best chance of success, do not try to interseed during peak perennial growth seasons, but interseed into cool season pasture during the warm summer months. Also, weaker perennial stands give a better chance of establishing interseeded annuals, so consider grazing the perennial stand hard before planting the warm season annuals.

The goal of this is not to create a complete canopy, as would be the case on cropland, because we want some sunlight to reach the underlying grasses. This is why the seeding rates are lower than our typical summer annual mixtures used on cropland. The light canopy creates a cooler microclimate that allows cool-season grasses to grow more than they would otherwise in the summer. An additional benefit to more diversity is better wildlife populations, ranging from deer to insects. Wildlife can not only provide more income opportunities through hunting or honey production but can also provide natural controls of many insect pests that afflict pastures like alfalfa weevil or armyworms.

Above: Cool season grass pasture with no interseeding.

Below: Same pasture, on the same day, but with an 8-way warm season interseed mix. Tons of extra forage and lots of soil benefits! What's not to like about this system?

Avoiding the Bermuda Triangle

In the south, you don't have to go very far to hear someone speaking fondly about Bermudagrass, as if she was a fantasy girlfriend. An eavesdropping beginning rancher may think Bermudagrass is the hottest thing going, and might make the mistake that Bermudagrass is a needed tool to run cattle! But be careful and don't get caught in "The Bermuda Triangle". This Bermuda triangle has nothing to do with getting lost at sea, but rather getting lost in a high maintenance relationship with spraying, haying, and fertilizing to maintain Bermudagrass production. In fact, you might even make your spouse jealous because of the huge amounts of time, money, and energy spent chasing the fantasy of good looking Bermudagrass! But there is hope through interseeding cool season annual forages into dormant Bermudagrass, which can provide an escape option out of this costly paradigm.

Photos by Brett Peshek

If you hope to interseed any pasture, the first thing to eliminate is the annual spray program. Broadleaf weeds tend to be very opportunistic plants seeking to take advantage of unused nutrients, sunlight, and moisture. When interseeding a pasture, mimic the types of weeds you are seeing (usually cool season broadleaves) and this will allow more desirable annuals/biannuals to fill the same void. While interseeding may not eliminate all your weeds, it can drastically reduce them through competition and the money spent on annual spraying can be added to your bottom line.

The interseeded broadleaf plants will also extend the grazing season of your pasture which allows for increased stocking rates. This extended grazing season reduces the need for hay and expensive haying equipment, which again adds to the profitability of the farm. By adding legumes like peas, vetch, clovers, and faba beans, the need for added fertility is reduced. This added diversity also encourages an abundance of life that wasn't present before, such as earthworms, quail, beneficial insects, and other wildlife.

With interseeding Bermudagrass, there are challenges that need to be addressed. First, Bermudagrass is a very good scavenger of free nutrients, particularly nitrogen. In order to reduce added fertility, select a large majority of legume

species or species that do not need lots of nitrogen to function. Brassicas, like turnips and radishes, should be used in small amounts as they have high N needs.

The second challenge is the establishment of the interseeded crops if the Bermudagrass canopy is thick or tall. In a taller canopy (more than 6 inches), many small seeded species will struggle to find sunlight once they germinate. However, larger seeded species do well here as the thick sod holds more moisture in the dormant season. Larger seeded species like buckwheat, sunflowers, peas, all vetches, and cereal grains have more stored seed energy to push through the canopy to find sunlight. If the canopy is below 6 inches we still encourage to use the larger species, but we can also begin to use more small seeded species like clovers, alfalfa, annual ryegrass, chicory, and plantain.

Lastly when interseeding into Bermudagrass, the two best "dormant season" timeframes are spring and fall. Spring tends to be more consistent with moisture as the dormant thatch provides a mulch for reducing evaporation. Fall moisture may be more variable as the Bermudagrass is still active but not aggressively growing.

To avoid getting trapped in the Bermuda Triangle of spraying, haying and fertilizing, be adaptable, have a diverse mix, and don't be afraid to experiment a little bit!

By Brett Peshek • Mountain View, OK

Brett Peshek has been with Green Cover Seed for five years and is currently the sales lead for Oklahoma and Texas. In addition to learning all he can about cover crops and soil health, he runs a small but efficient herd of Red Angus cattle at his farm in Oklahoma.

Grassfed Beef and Soil Health: Profit, Possibilities and Promise

The fastest growing market demand in the beef industry is for grass finished beef. As compared to grainfed, grass finished beef has a healthier balance of Omega-3 fatty acids, is higher in fat-soluble vitamins like vitamin A and vitamin E, and is higher in the cancer-preventative conjugated linoeic acids (CLA's). Many consumers also see grass finishing as a more humane and environmentally sound way of feeding cattle than feedlot finishing.

However, there can be problems with grass finished beef. First, because grassfed is not being produced on a large scale and run through the large packers, it is often hard for many consumers to find. Secondly, many consumers have had a cut of "grassfed" beef that gave them a very poor eating experience: tough, dry, full of gristle, and with a strong "gamey" flavor. Much of this so-called grass finished beef was just a salvage product from a reproductive animal, an old cow or old bull. While these cull animals were not fed grain, they also were not truly finished at all and were not managed to produce good quality beef.

To make good quality beef, the following criteria must be met: the animal must gain at least 1.75 pounds of gain a day every day of its life until maturity (any day in which animals don't gain, marbling cells that give meat juiciness are replaced with gristle that makes meat tough) and it must be on a high plane of nutrition at time of harvest, with a forage high in glucose content for good fat deposition and not excessive in protein, which can cause gamey flavor.

In order to provide high quality grass finished beef to the consumer, a joint endeavor between Pharo Cattle Company (a genetics provider specializing in low maintenance animals that fatten easily on grass) and Cactus Feeders (one of the largest cattle finishing operations in the world) was undertaken to see if it was possible to economically produce a high quality, grass finished beef on forage alone and on a scale big enough to make it worth the while of a major packer.

To make this happen, these companies sought the assistance of Green Cover Seed to develop a sequence of annual forages that could be grazed 12 months out of the year and provide adequate quality for the animals to fatten by 18 months of age, a very tall order! The first year, a trial project was performed that consisted of a rotation of a spring planted blend (primarily oats and peas), and as this was grazed off it was planted to a mix of summer annual forages (BMR sorghum-sudangrass, pearl millet, sunn hemp, cowpeas, buckwheat, okra, sunflower), which was followed by another winter annual mix (rye, radish, annual ryegrass, oats). Other acres were planted to a stockpiled photoperiod-sensitive BMR sorghum-sudan for winter grazing.

The main drawback to this rotation was that the gap between grazing one crop and the time it took for the next crop to develop was too long, and the stockpiled sorghum did not provide high enough gain in the winter. However, this initial experiment was successful enough to expand the project with a modified rotation to eliminate the gaps.

The plan now consists of dividing the pivots in half, with each half in a slightly different crop rotation: the first, a rotation of a winter mix (cereal rye, annual ryegrass, oats) rotated with a summer annual grazing mix (BMR sorghum-sudangrass, pearl millet, buckwheat, sunn hemp, cowpeas, crabgrass, mung beans, okra, sunflower); the second, a rotation of another winter annual mix (willow creek wheat, annual ryegrass) and another summer annual mix (BMR corn, pearl millet, sunn hemp, cowpeas, buckwheat, mung beans, sunflower), with the two halves of the pivot grazed in sequence to provide nearly year-round, uninterrupted grazing. Since the stockpiled sorghum did not provide gains high enough, alternatives for winter grazing are being explored. One is to simply expand the acreage of rye cover crops on pivots currently in corn and cotton; another is to plant pivots for dedicated winter grazing to perennial forages that maintain good grazing quality in the winter, like a novel endophyte tall fescue or summer dormant fescue.

Photos by Dale Strickler

High quality mixes with ryegrass, rye, and triticale are the base of the fall planted mixes in this program.

Photos by Dale Strickler

Above: Highly productive sorghum based mixes make up the base of the summer mixes due to heat tolerance and excellent regrowth. Below: Taken after the cattle have grazed through a paddock—note that not everything has been eaten to the ground to allow for regrowth and a second grazing.

We spoke with Tyler Dinkel, Grazing Manager at Cactus Feeders, about his thoughts on the project.

Q: What have been the best parts of the grass finishing project so far?

Tyler: Probably the most impressive thing has been how much feed we can produce using rotational grazing with daily moves. It is fun to watch how fast things can regrow after we move the cattle off a paddock.

Q: What have been the drawbacks and difficulties you have had to overcome?

Tyler: The biggest thing has been the learning curve in matching animal numbers to available forage. It takes a few moves to train your eyeballs to make sure the animals have enough to eat and you are also leaving enough residue behind to protect the soil. Every batch of cattle has a little different level of intake, and Holsteins are completely different than our beef breeds. Providing adequate drinking water to over 1000 head on a pivot and making the fences so the pivot can walk over them was an initial challenge as well, but once we figured that out it has been pretty smooth.

Q: One of the touted benefits of grazed cover crops is the benefit to the soil. Have you seen soil health benefits?

Tyler: Definitely. The soil just gets mellow. Our best results were where we also inoculated the seed with mycorrhizal fungi. In one season our organic matter test went from 1.6 to 2.2 %—that is a huge jump. I don't think our other pivots were that dramatic. They have all visually improved, they are just darker and more mellow over time.

Q: What can you share about the economics of finishing beef animals on irrigated annual forages? How many animals are you running on a pivot? What kind of performance are you achieving?

Tyler: It's penciling out well. The cost of gain is really cheap, especially on the lighter cattle. It also gives us flexibility in when we want to market animals. We can run them on forage and delay putting them in the lot and hit a better marketing month later on. We are stocking from 2.5 to 4 animals an acre, depending on animal weight and forage production. Our gains usually run from 2 to 2.7 pounds per head per day

Q: I understand that this project won Cactus Feeders an award for environmental stewardship. Can you elaborate?

Tyler: We were one of 20 statewide winners of the Texas by Nature Award, a program developed by Laura Bush to showcase Texas businesses who have done environmentally beneficial projects.

Q: Where do you see this project going in the future?

Tyler: We definitely plan to expand as we learn more and work out the kinks. One change is that we do plan to incorporate more perennials into the system, to reduce the number of trips we have to make in a year and to give us a little more forgiveness with weather events.

All in all, despite a lot of minor setbacks inherent in any new enterprise, it appears that grazing irrigated annual forages might provide a profitable and environmentally sound alternative or enhancement to traditional feedlot finishing, with one option to graze animals until they are close to finish weight with a short grain finishing period just before slaughter for the traditional grain fed beef market, and the other option to finish animals entirely on forages and sell as grass-finished beef.

To achieve maximum gains on grassfed beef, high levels of management must be employed and fencing and water for daily or semi daily moves must be thought out. Here are 1200 head of steers in one paddock drinking from a creative watering solution developed by Cactus Feeders.

Cattle as the Cash Crop

Farming on the High Plains has always been an adventure. Limited rainfall has made the raising of grain crops risky, with some years being productive and other years of complete failures. Strategies developed for dealing with the infrequent rain were deep, frequent tillage, and fallowing. Deep tillage was proposed to loosen the soil as deep as possible for "better" water infiltration and storage. Fallowing was intended to manage water by preventing plant growth for long periods to raise a better grain crop the following year.

In hindsight, these practices were colossal mistakes. Tillage oxidized soil organic matter, which decreased soil water-holding capacity and led to collapsed soil aggregates and pore space, significantly decreasing water infiltration. Fallow was also counterproductive as we failed to realize that preventing plant growth robbed the soil of vital root exudates responsible for producing soil organic matter. Thus, fallow didn't "rest" the soil, it starved it. Together, tillage and fallow have depleted our soils on the High Plains and made them a shell of what they once were. The recent move to no-till in the area over the last couple decades has helped moisture availability, but fallow is still an integral part of the system and is an impediment to improving the soil. The problems inherent in this system are erratic yields, high weed control costs during fallow due to herbicide resistant weeds, the need for chemical fertilizer to sustain yields, and high harvest cost per bushel due to low yields. All of these factors combine to make grain cropping on the High Plains a very marginal enterprise economically.

Photo by Dale Strickler

Here is proof of a broken water cycle with standing runoff water from a recent rain while the surrounding soil is powder dry and blowing. Poor infiltration caused by tillage is the root cause of both the wet hole and the powder dry upland soil.

Why did we go down this route? It was because we thought we HAD to grow water intensive grain crops which makes no sense in arid areas. The native vegetation was mostly perennial grasses and deep-rooted forbs that produced very little seed (which requires more moisture) and was harvested by ruminant animals like bison and antelope. Since the most successful agriculture systems are developed by mimicking nature, perhaps we should strive to emulate the native prairie when designing our agriculture systems.

One such producer who is mimicking nature is John Niswonger of Wallace, KS. John has transitioned much of his farm from the typical wheat-fallow-sorghum-fallow system, to a sequence of continuous cropped mixtures of grazed cover crops. BMR sorghum-sudan (summer grazing) and forage sorghum (winter stockpile) are mainstays of John's mixtures due to their high production and efficient use of water. Winter annual forages like wheat are also incorporated into the system to provide high quality green feed in late fall and early spring. The native grass pastures of the area are incorporated into the grazing system, using an adaptive multi-paddock grazing system, so that pastures are grazed intensely once during the early part of the growing season and then allowed to recover until after frost, when they can be grazed in the dormant season. This late season rest has allowed his pastures to develop from primarily buffalograss into stands of big bluestem and other tall grasses.

Wheat in the system can be grazed in dry years, or in wet years can be allowed to produce a grain crop. Legumes are included in the mix to provide nitrogen, and since grazing returns most of the mineral nutrients back to the soil, fertilizer requirements are very low. Weed control costs in this system are also low, because the most troublesome weeds like kochia and Palmer amaranth are actually very good forages and are readily eaten, which turns them into an asset rather than an expensive menace. Most importantly, moisture is converted very efficiently into money. John reports that the economics of his operation have improved dramatically since this transition. He is raising a cow-calf pair on four acres of cropland and two acres of native pasture and feeding very little hay. Almost the entire needs of the cowherd are met by grazing alone.

A sample grazing sequence in a system like this might include the following:

- Winter: graze on a stockpiled mix of primarily nonheading forage sorghum, with sunflowers, guar, and collards added for protein.
- Spring: winter annual mix based on rye, triticale, or graze-out wheat.
- Early summer: native grass.
- Late summer: sorghum-sudangrass, pearl millet, cowpeas, sunnhemp, mung beans, buckwheat, and okra.
- Fall: dormant native grass with protein supplement.
- Late fall: winter annual mix if it develops enough for fall grazing.

Photo by Dale Strickler

Above: Niswonger's pasture that was mob grazed in June but has now rested 75 days while his cows were grazing cover crops. The big bluestem regrowth on this is very impressive for Western KS and this can provide winter stockpile grazing or be setup for tremendous production next year.

Below: A neighboring buffalograss pasture with continuous grazing throughout the summer. No cover, poor water infiltration, poor yield, and extremely low stocking rates.

Photo by Dale Strickler

Niswonger is not alone in his approach to farming the arid High Plains. Jacob Miller of Culburtson, NE, graduated from University and returned to the family farm in 2013 with big plans. Miller remembers, "I was going to be a farmer so I went and bought a combine and grew wheat, and I grew milo, and I grew soybeans. And I didn't make a damn dime farming." It only took two years to discover what his father already knew – that grain farming wasn't going to work—especially amid the current economy. Like Niswonger, he decided to convert his cash grain production acres to cover crops for grazing.

Photo by Jacob Miller

The goal is grazing every acre they have and grazing 365 days a year. Miller has largely kicked the hay habit by keeping something growing all the time. A variety of cover cropping strategies are used, including spring-planted mixes of peas, oats, barley, and rapeseed which cattle graze in early summer and summer planted sorghum based mixes grazed through the fall and winter. Like Niswonger, fall planted mixes of rye and hairy vetch are grazed from March to the beginning of June. The aggressive and tough nature of rye makes it a favorite choice as it typically gives the most production and best soil building properties – even under the toughest of conditions. Native range is rotationally grazed between cover crops.

The economics of this system works. On yearling calves, the cost of gain is $0.45 to $0.65 per pound (depending on what is being grazed) with a typical summer average of 2.3 ADG and an average 400 pounds of beef per acre. Miller calves in sync with nature, starting in May and keeps costs in line and improves his genetics by raising his own replacement heifers and bulls. Ever the entrepreneur, Miller has also started a fencing supply company (www.facebook.com/livewiresolar/) and sells a full line of quality products as well as some pretty cool customized solar powered energizer solutions.

Photo by Martin Kunz

In addition to the economics, soil health has improved with noticeable increases in soil organic matter, infiltration rates, and biological activity. This "farming in nature's image" method has also led to increased populations of mycorrhizal fungi, earthworms, wildlife, and birds.

Grazing cattle in these arid areas makes a lot more sense then tillage and fallow and grain production. By mimicking nature, Niswonger and Miller have improved their soils, their bottom lines, and their quality of life.

Winter Stockpile Grazing

Everyone who manages pastured livestock knows that feed in the form of bags, buckets, or bales is far more expensive than grazing. This has traditionally made winter, when nothing grows, the most expensive time of year to maintain animals, however, there are alternatives to expensive mechanically harvested feed.

The best way is to use some form of stockpiled forage such as uncut nonheading forage sorghums that are allowed to grow throughout the summer and stand through fall and winter. Frost-killed sorghum is low in protein but can provide adequate energy for a nonlactating cow or ewe, and the per acre yields can be quite impressive. Sorghum is also quite economical to plant and grow and is very efficient at converting moisture into dry matter. It is not unusual for sorghum to produce 2 tons of dry matter per acre per month of growth. There are a few important management tips for utilizing sorghum for standing winter feed.

First, select a sorghum that does not produce grain which can cause acidosis. Male sterile hybrids, like our BMR400, do not produce viable pollen, so unless they are in close proximity to another fertile sorghum variety, will not produce grain. They continue photosynthesizing after heading, however, but with no grain to fill, the sugars simply build up in the rest of the plant, which makes for a very sweet and palatable plant with high energy content. Photoperiod sensitives types, like Sweet Forever BMR, begin to head out when the length of day is less than 12:20 (mid-September) and are almost always killed by frost before making viable grain. Photoperiods are the most moisture efficient of the sorghums and are well suited to arid areas for stockpiling. Planting a long maturity sorghum late, like our 120 day Silo Pro, is the preferred method when the sorghum planting is delayed (after wheat harvest), so that the sorghum simply does not have time to mature before frost in most areas. Many varieties, like our Sweet Six BMR drystalk hybrid, or dwarf BMR sorghum-sudan work well in the "cut once and let the regrowth stand through winter scenario". The first growth can be baled, or it can be simply swathed and left late in the season for swath grazing. One advantage of the cut once method is that the ground is now open to drill a winter annual mix, such as oats and rye, into the stubble to come up along with the sorghum regrowth and provide additional grazing that is high in protein. Swath grazing is also increasing in popularity, as the cost of baling is eliminated, and the quality is often better than sorghum allowed to freeze out.

The second management step is to ration off grazing to only one or two days worth of feed at a time to limit trampling. Using portable fencing reels with polywire and step in fence posts is a very cheap and time efficient way to increase the percentage of plant material that gets into the animals versus being trampled. Some trampling is acceptable, and in fact allowing animals to strip the leaves and trample the stems for soil armor may be a way to let the animals get the most nutritious parts of the plant while the soil gets the long-lived protection it needs. It is obviously hard to move a polywire in tall standing sorghum. Some have found that using an ATV to pull a mineral feeder sitting in a tractor tire to be an easy way to knock down a path for the next fenceline.

Photos by Brett Peshek

Even though this field looks like dead and low quality forage, it is actually very high in nutrition. Above: This cow is getting a big energy boost from eating a black oil sunflower head and consuming the 40% oil content seeds from this summer planted winter stockpile mix. Below: Not to be outdone, this girl is getting her protein snack from finding a winter killed cowpea plant in the winter stockpile jungle.

The third important management aspect is to ensure that your animals are getting sufficient protein. One way is to simply supplement what the animals need, but the cheaper way is to grow the protein right along with the sorghum. Guar is a summer annual legume that produces high protein beans that, unlike other legumes, remains in the pods well into winter. Sunflowers also produce high protein seeds that can supplement the low protein sorghum. Having an adjacent field of high protein wheat or green cool-season cover crop can also be used as a protein supplement but the grazing intake must be managed.

The Effect of Grazing on Plant Root Growth

Over the years, I have seen many grazing operations in many parts of the country. I have seen places that never seem to grow as much grass as they should, and I have seen places that always seem to have lots of grass. Likewise, I have seen places that have been hurt by the extreme weather of the past several years, and I have seen places that have tolerated the extreme weather quite well. The places that have lots of grass and are doing well don't necessarily have better soil or get more precipitation, and they may not be stocked lighter or rested more days per year. So what is the difference? Roots and the effects that management has on the roots.

I have always known that grazing management affects roots, but it was made crystal clear to me when I was introduced to work that F.J. Crider published in 1955. Through several experiments, using various perennial grasses, he showed the effects that forage removal has on root growth. He used both cool and warm season grasses including smooth brome, tall fescue, switchgrass, bermudagrass, and several others. In one experiment, Crider showed that when more than half of the forage is removed from a plant, root growth stops within the first day or two afterward, and stays stopped from six to eighteen days, with an average of eleven days. In the real world, this means if cattle have the opportunity to graze more than half of the top growth of a perennial forage grass, at an interval less than eleven days, the roots never get to recover. If the roots don't recover, eventually, neither will the top.

In another experiment, Crider showed the effect that a single removal of top growth, in ten percent increments, has on root growth. When forty percent or less of the forage is removed, zero percent of the roots stop growing. When fifty percent or more of the forage is removed from perennial grass, an increasing percentage of the roots stop growing. When ninety percent of the forage is removed, one-hundred percent of the roots stop growing. In other words, leaving more than half of the forage any time a perennial grass plant is grazed during the growing season allows the roots to continue to grow. If the roots keep growing, so should the forage. Not only did higher percentages of forage removed result in greater percentages of roots that stopped growing, the higher percentages of forage removed also resulted in greater lengths of time before the roots resumed growth. Thirty-three days after top growth removal, plants with eighty and ninety percent of their forage removed still had a portion of their roots that had not resumed growth.

	% Root Growth Stoppage Three Days After Forage Removal			
% Forage Removal	Test 1	Test 2	Test 3	Test 4
90	100	100	100	100
80	100	100	91	81
70	78	97	77	76
60	50	80	54	36
50	2	8	38	13
40	0	0	0	0
30	0	0	0	0
20	0	0	0	0
10	0	0	0	0
0	0	0	0	0

This represents four tests with three different grass species. From Crider, 1955.
Note that somewhere between 40% and 50% of the forage can be removed without stopping root growth.

So, whether cattle are grazed rotationally or continuously on perennial grasses, removing half or more of the forage at a time stops root growth. However, leaving half or more of the forage allows root growth to continue uninterrupted. If the roots grow more, the forage grows more, and in the long run, more forage will come from the half that is grazed.

The entire article by Crider can be found by looking up Root-Growth Stoppage Resulting From Defoliation of Grass by Franklin J. Crider, Technical Bulletin No. 1102, United States Department of Agriculture, February 1955 or by going to www.greencoverseed.com.

By Jim Johnson • Ardmore, OK
Noble Research Institute

Johnson serves as a soils and crops consultant in the producer relations program, where he assists regional agricultural producers with soil fertility testing, recommendations and management; pesticide recommendations; integrated pest management; sprayer and planter calibration; variety selection; and agronomic best management practices. Johnson has more than 20 years of experience in plant and soil sciences. Johnson, his wife, and children, also run a small cow-calf operation in south-central Oklahoma.

Prevent Plant

It's been a tough year for many producers throughout the Plains and Midwest with wild weather and excessive rainfall causing record acres going into prevent plant programs. While no one wants to take prevent plant, this cloud can have a silver lining. Many farmers have been stuck in a corn/soybean rotation (or lack of rotation) for many years so this can be an opportunity to add diversity to the system. A diverse multi-species cover crop mix planted into prevent plant acres can greatly stimulate soil life and soil biology, while suppressing weeds, interrupting disease cycles, and even produce and cycle nutrients for next year's crops. For growers in livestock regions, you can also provide valuable livestock forage (be sure and follow the Prevent Plant rules for grazing).

Lebanon, IN farmer Dave Chance was not exempt from prevent plant this spring, and had to drill covers on 600 acres of his 2,200 acre corn and soybean farm. Chance is passionate about the health of his soil and saw this setback as a golden opportunity to add the diversity from the cover crops that will positively impact the long-term production of his farm. While never an easy thing to do, Chance encourages others, "Instead of looking at the negative of not growing corn, focus instead on how the covers can increase soil health and how the legumes will potentially reduce nitrogen input costs next spring. This simple shift in thinking will be the difference between success and failure for first time cover croppers."

Chance is adamant about using diverse cover mixes whenever he can and the ingredients in his cover crop recipes include legumes, grasses, brassicas, and broadleaf species to give his soil biology a full spread buffet of energy rich carbon root exudates. His five favorite mixtures range from 3 to 16 species each and more than 20 species are used throughout the farm. Chance goes on to note, "Just like in corn and beans, variety selection can be the difference between success and failure so do your due diligence and do your own testing and research to learn about what is available and take advantage of specific traits bred into the cover crop varieties that will lead to more consistent performance."

Photo by Colten Cotterton

Currently two of his favorite legumes to include in mixtures are cold tolerant FIXatioN Balansa Clover and Frosty Berseem Clover from Grassland Oregon. FIXatioN Balansa Clover can contribute up to 200 pounds of nitrogen per acre and yield 5 tons of dry matter in a single growing season. It's deep tap root system also helps with compaction, soil drainage and water infiltration. Frosty Berseem Clover has specifically been bred for fast establishment, late maturity and the ability to survive in temperatures as low as 20°F.

Selecting for variety traits has been the difference between cover crop success and failure on many occasions for Chance Farms. Two of his favorite legumes to include in mixtures are FIXatioN Balansa Clover and Frosty Berseem Clover from Grassland Oregon. Both have been bred to fix notable amounts of nitrogen and to produce significant biomass while surviving in sub degree temperatures.

Chance's final piece of advice for others is to "look at your cover crop venture as a marathon—not a sprint. Simply putting a cover crop in the ground to collect a government check and then turn around and go back to the way you've always farmed won't yield the full benefits of cover crops. It takes years of consistent management to rebuild soil health and capture the full potential of cover crops, but the long-term rewards from cover crops will be worth it."

We hope that none of you will have any prevent plant acres in 2020 or beyond, but sooner or later, most of us will face this challenge, and when you do, remember the lessons of 2019 and be prepared to take advantage of the opportunity to add diversity of both plants and biology to your system. Your soils and your future crops will thank you for it!

Regenerative Wildlife Ecology

The principles of soil health have positive, compounding effects on all wildlife species. The time-tested, synergistic relationships between soil, plants, and herbivores are paramount to a functional ecosystem because everything in nature is interconnected and inter-related.

Modern food plotting began in the 1930's and was primarily dominated by monoculture stands of clover. Sadly, from the herbivore's perspective, the commercial side of food plotting really hasn't evolved in the last 90 years. The commercialization of food plot products has resulted in a narrowly focused race for "improved" varieties while sacrificing plant species diversity and nutrient density. The shift from nature's high species diversity to large scale monocultures and low diversity food plot systems has resulted in plant landscapes that lack a broad selection of primary and secondary compounds. Like modern agriculture, modern food plotting relies too heavily on soil disturbance, heavy herbicide and synthetic fertilizer use, and monoculture cropping systems with simple rotations. Deer and other wildlife thrive on diversity, yet we've eliminated it from their habitats.

Photos courtesy of Jason Snavely

Crimping and planting in a single pass give both weed control and fertility to the food plot of forage soybeans that will grow here.

Many food plot products consist of fewer than 7 different species/plant types and are developed in the absence of a calculated approach. The answer lies in planting diverse cocktail mixes in well-thought-out blends that seek species complementariness and offer maximum soil and animal health. Diverse cocktails should include the right species and proportions of legumes, grasses, forbs, and brassicas that tighten in-field nutrient cycles and allow "food plotters" to rely less on the heavy use of synthetic fertilizers.

This diversity of plant compounds offers wildlife a complex nutritional profile with nutritive, antioxidant, and medicinal values. Biochemically diverse foodscapes are necessary for wildlife to reproduce and fend off disease, parasites, and predation. When free range animals are presented with diverse species blends to complement native plants, they appear to possess the ability to self-medicate and manage parasite loads by optimizing their diets with nutritional wisdom. For optimal nutrient utilization in growth and reproduction, deer demand a broad selection of plants that are readily available. This foraging option affords deer the opportunity to balance potential toxicities in their diets, ultimately leading to higher reproductive rates, larger antlers at maturity and healthier populations, overall. Unfortunately, we're not making these options available when using systems that lack diversity and result in low productivity and disease. Cover crops complementing native plants can add the diversity needed in wildlife food plots and clearly offer beneficial synergies.

The momentous paradigm shift in recent years surrounding soil health, food production, and agriculture has offered a promising outlook for all wildlife species; from honey bees to white-tailed deer. All terrestrial and aquatic wildlife, from sub-aquatic micro-organisms to large, free range herbivores, proliferate in the wake of farming in nature's image. Diverse plantscapes resulting from the establishment of cocktail blends no longer force animals to disperse in search of needed concentrations of vitamins, minerals, energy, and protein as well as primary and secondary plant compounds. After two decades of private wildlife consulting, I have never been as excited about an advancement as I am about regenerative wildlife agriculture (RWA).

Drop-Tine Perennial Reload is a diverse and nutritious buffet!

Jason R. Snavely • Bloomsburg, PA
CWB Certified Wildlife Biologist
Drop-Tine Seed Co.

To learn more about these principles or about Drop-Tine Seed, please visit Jason at www.droptineseed.com.

Natural Intelligence Farming

Editor's Note: I first met Ian and Dianne Haggerty in February of 2019 when we were all speaking at the Paicines Ranch. After hearing their story and seeing what they are doing on their farm, and the stunning results that they are seeing, I knew that I wanted to share it with other people. The Haggertys also spoke at the 2020 No-till on the Plains conference to share their information. - KB

"Facilitate positive global change by rebuilding soils in semi-arid regions, producing premium food and fiber, and supporting the nutritional needs of humanity to optimize health." Big and bold words, but this is the passion of Ian and Dianne Haggerty who are doing just this on nearly 50,000 acres in the arid regions of Western Australia.

This has not always been their focus, but it grew out of frustrations and failures. After years of traditional farming, the Haggertys realized that they were subject to drought and rising input costs and poor fertilizer performance. Much of the little moisture they received was lost to evaporation, and hardpans in their soils were severely restricting root growth. Ian Haggerty recalls, "It didn't take long for us to realize that moisture in the soil was key to profitability and that hanging onto that moisture was critical to make a viable crop out of a poor spring. This fact, along with a questioning mind and noticing that there were discrepancies between soil test and tissue test results, sparked a drive for real answers. Reducing risk and increasing profitability year in and year out were key goals for the business to progress."

So, Ian and Di started to research biologically-based farming systems with the aim of increasing their soil's moisture holding capacity and microbial populations. Together they climbed up a steep learning curve and integrated some of the world's top biological knowledge. They recall their educational experiences: "Dr. Elaine Ingham's message of the miracle work of soil microbiological communities in providing optimum balanced nutrition to plants and prevention of disease and insect attack through soil health resonated with us. At the same time, we consulted with Jane Slattery of South Australia to develop an understanding of ruminant nutrition and interconnectedness with landscape health. Working on both the soil and animal health aspects concurrently enabled some wonderful synergies to express and assist with fast tracking the ecological progress of the farm. We were privileged to be introduced to Dr. Christine Jones, Dr. Maarten Stapper, and Walter Jehne, who had considerable knowledge on working soil health principles in Australian agricultural environments. Dr. Jones' 'liquid carbon pathway' answered many questions of what was happening within the soil to improve its friability and moisture holding capacity. This was confirmed with deep soil carbon testing in 2012 that showed our soil carbon increased by 41% compared to neighboring soil in the top 30 cm."

"Natural Intelligence Farming" is the term the Haggertys use to describe their system that harnesses the dynamic, natural relationships that exists between the soil, the plants, and the biology in the farming ecosystem. These complex relationships involve mutually beneficial interactions between the soil, plant seeds and roots, microorganisms, and ruminants that feed on the plants and cycle dung and microbes back to the soil. The key to their success and natural intelligence farming is to not hinder or obstruct the interactions that support and inform these relationships—in other words, to work with nature and not against her!

The Haggertys believe that their agricultural methods can make a significant contribution to improving global trends in environmental management and human health. There is an existing and growing body of scientific research supporting a wide range of benefits associated with these farming methods, including:

- Carbon sequestration while producing optimal food and fiber.
- Increased biodiversity, particularly microbiological biodiversity in soil.
- Zero chemical residues tested in grains grown.
- Nutritional diversity and balance in foods grown.
- Elimination of synthetic fertilizers.
- Increased diversity in the microbiome.
- Return of diverse native plants throughout the farming landscape.
- Production of fully pasture fed meat that is high in Omega-3, conjugated linoleic acid, vitamin E, and has greater mineral diversity.
- Greater reliability in grain crop yields.
- Crop disease resistance resulting in decreased fungicides and pesticides.

Cropping

Seeds are microbiologically coated before being direct seeded into a seed trench that is supplemented with natural fertilizers based on high grade worm liquid and compost extract. This ensures that the plant is biologically supported from germination to early growth. By supporting and encouraging the soil/plant root microbiome, the plant's immune system is strengthened so that no fungicides or pesticides are necessary. By not using water soluble fertilizers with the seed, extensive root system growth is stimulated, and the plant is able to reach wider and more deeply for moisture and nutrition. The thick rhizosheath on the

roots enables the crops to penetrate acid subsoil and enable positive regeneration. These roots and associated microbiology hold the soils together, improve soil structure, air and water penetration. The improved soil carbon levels then enable this water to be retained in the soil for longer periods along with nutrients to be available for plant growth. Crop quality is checked by periodic testing of tissue nutrient levels, which the Haggertys find more reliable measure then soil testing.

Photos by Ian and Di Haggerty

Grazing

Once grain is harvested, the stubble of the crop grown in this high microbial environment provides nutritious grazing fodder for their Merino sheep. Enhanced microbial activity in the soil, and the use of specially-bred sheep as the "farm machinery" has improved soil function, structure, and water-holding capacity and continues to value-add to the productivity of the landscape. In due course, remnant stubble is trampled down and is digested by fungi to add to the organic carbon in the soil. The cycle is completed with the return of nutrients and microbes to the soil via the sheep manure and urine. The sheep thrive on cereal stubble and native shrubs and grasses as their rumen flora is totally adapted to maximizing nutrient extraction from roughage. The livestock do not receive any grain supplementation. "Our sheep have developed into hardy, efficient producers with minimal artificial support and highly adapted to our local environment. The cropping and hay production contribute to our production of premium wool and lamb, but the sheep are playing their part in fertilizing the land and working the soil for us. Enhancing animal health and soil health conjointly facilitates a positive epigenetic spiral in this agricultural ecosystem," reflects Di Haggerty.

Ian and Di are confident that their products are superior to those produced by conventional agriculture using chemical fertilizers, pesticides, and fungicides. They go on to say, "We can consistently demonstrate that our produce, be it grain, meat, or fiber, is free from these chemicals. We also believe that our produce has greater nutritional and microbial diversity. We have established that there is a market for produce that can demonstrate sound ecological rejuvenation, high animal, plant, soil health outcomes and ultimately human health outcomes." A growing number of consumers are seeking such products as the awareness of how purchasing decisions can influence planetary health is increasing. True ecological value is beginning to be factored into the market place creating a niche similar to organic.

As with any growing enterprise, there are obstacles. The Haggertys have limited infrastructure and capacity to segregate their products in the logistic chain that transports the produce from the farm to the consumer. They are pursuing solutions as they believe that the value of identity preserved products will justify the required infrastructure investments. An exciting relationship has evolved with an artisan flour miller/baker in Perth who is sourcing grain from the Haggerty farm to supply flour, sourdough bread, and various pastries to customers and restaurants.

Future Goals

Ian and Dianne plan to continue to expand and demonstrate the power of natural intelligence agriculture, while also helping other farmers do the same. They are working to establish the logistic chain for a segregated market initially for grain, meat, and wool and also are developing partnership ventures to add value to their products. They also hope to reintegrate indigenous culture and knowledge of land management, bush foods, and medicines. An on-farm research and education center to allow people to see, dig, taste, and experience natural intelligence food where they are produced is also a planned venture.

Biotic Farming

"Biotic Farming", a phrase coined and adopted by Brendon Rockey, is all about observing and working with nature and taking care of the soil. Rockey's San Luis Valley, CO potato farm has undergone some radical changes over the past 20 years as they took a hard look at what wasn't working on the farm, and opted to change things. The result—the birth of Biotic Farming.

Rockey states, "Soil health is imperative and the fundamental principles are universal, regardless of the crop being grown." In conventional agriculture, weeds, diseases and insects are attacked with a "let's kill it" mentality, but eventually resistance develops, effectiveness is decreased, and the natural living systems which could have helped solve the problem has been decimated. Rockey reflects, "We realized that we could either be pro-biotic, or anti-biotic. We chose to wipe the slate clean and start again with being pro-biotic." They are now chemical-free with less weeds, disease, and insects, and improved soil fertility and structure, all while decreasing water usage and harvesting high quality potatoes.

Flowers

Aphids and thrips are a serious pest problem in potatoes, but conventional insecticide control is harmful to all insects and will ultimately negatively impact soil health. Leveraging beneficial insects is a big part of the biotic strategy. Rockey plants flowering strips of annual cover crops in and around fields to serve as insectary strips for both beneficial insects and pollinators (even though pollinators are not necessary for potato production). Beneficial insects are attracted and provided with habitat for nutrition and reproduction. These "good guys" are the defense force against the "bad guys" like aphids, a disease spreading vector, and thrips, a tiny spud leaf feeding critter. The insectary strips have eliminated the need for insecticide applications, and while pests are not entirely eliminated, the predator/prey insect population is in balance and damage is kept below economic thresholds.

Photos by Brendon Rockey

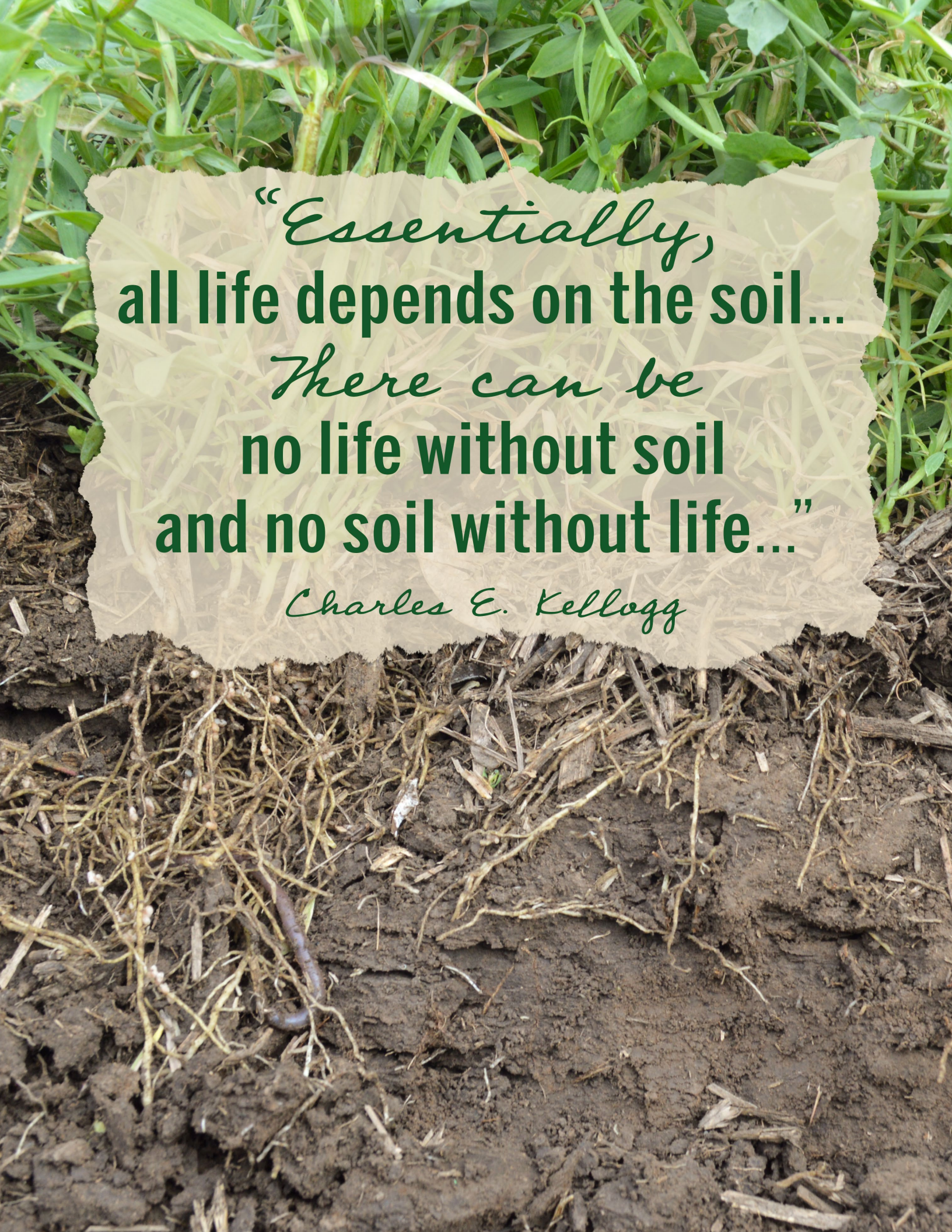
Cover crop species are selected to bloom throughout the growing season, giving season long forage for bees, butterflies, wasps, beetles and other beneficial.

Companions

Never one to be complacent, and after witnessing the benefits of plant diversity in his cover crops, Rockey decided to attach two Gandy boxes to their Grimme potato planter to seed companion plants like chick peas, field peas, chickling vetch, fava beans, and buckwheat, right into the seed potato crops. The legume heavy companion mix fixes nitrogen, supports phosphorus mobilization, and the flowers create additional beneficial insect habitat, which is crucial for successful biotic integrated pest management (IPM). Colorado State University research on this practice concluded that the companion plants provide the potato crops with a Potato Virus Y defense.

When not in potatoes, the traditional rotation crop was barley, but today it is a diverse cover crop mix of nearly 20 species of plants. This green cover menu feeds the soil and the soil biology as a carbon fixing green manure buffet. "We get the benefits of each of these species every single year," Rockey said of the diversity of plants in his green manure mix. "Each of the green manure crops has a specific benefit, and the plants collaborate, not compete and these covers have made huge changes in our soil-borne pathogens and soil fertility." This soil health translates to increased potato plant health with higher brix level and makes these healthy plants less attractive and susceptible to insects and diseases.

While it has taken Brendon and his crew 20 years to make the changes and implement their Biotic Farming system, he thinks it can be done much quicker for those with a passion to change. "It's a choice between promoting, enhancing, and nurturing life into the system, or being 'anti-biotic' and killing everything—and anyone can make the choice to change," concludes Rockey.


"Essentially,
all life depends on the soil...
There can be
no life without soil
and no soil without life..."
Charles E. Kellogg

Problem Soils: High Salts and Salinity

One of the tactics used by the Romans in their war with Carthage was to salt the crop fields so that Carthage starved. Unfortunately, it seems like the Romans must have traveled more than we thought, because we have soils too salty for good growth over way too much of the world. Salt definitely makes cropping more difficult, but it does not mean that it is impossible to grow plants on salty soil. There are management techniques to help us do so, and of course those techniques involve the use of cover crops.

Photo by Dale Strickler

The Romans did not do this, but the end result is the same. This high salinity field in South Dakota will be very unproductive unless action is taken to remedy the situation. Notice all of the white salt residue on the soil surface that is left after excess water evaporates.

Salt affects plants primarily because salt has an attraction for water and can pull water away from plants. Therefore, techniques to help increase the supply of soil moisture will help plants deal with salt. Primary among those is the creation of a mulch on the soil surface, which will help increase rainfall infiltration and slow evaporation. When rainfall infiltrates the soil, salt is moved down in the soil, away from the root zone. When soil moisture evaporates, salt moves back up to the soil surface and into the root zone or even the seed germination zone. A means of eliminating salt from a soil involves the installation of underground drainage tubing that empties somewhere downhill from the field, then flushing the salt out with irrigation or rainfall; in either case, a good mulch from residue of either a cash crop or a cover crop (or both) is very helpful in aiding this process.

Since few cash crops tolerate salt very well, it is often the job of a cover crop to create the initial mulch layer. Cover crops that tend to be somewhat tolerant of salt include barley, rapeseed, sugar beets, sorghum-sudan, Japanese millet, sweetclover, and rye. Another approach is to simply plant a very high seeding rate of a cheap sorghum blend, just to get as many plants out there as possible to create the initial mulch.

Photo by Keith Berns

Photo by Brett Peshek

Saline tolerant crops like barley and sweet clover can be used to begin the healing process of high salinity soils—not only will this get organic mulch on the ground but will also start to jump start the biology of these soils also.

If the soil is so salt affected that crop growth is very difficult, it may be the best option to seed the land back down to salt tolerant perennial vegetation. Perennial forage plants that tolerate salt include tall wheatgrass (the variety Hercules is far more palatable than older ones like Jose or Alkar), Saltlander green wheatgrass, fourwing saltbush (an evergreen shrub that holds its high protein leaves all winter) forage kochia (not the weed kochia, but a distantly related perennial forage plant that does not spread and also stays green all winter long), alfalfa, strawberry clover, and birsdsfoot trefoil. If the soil is also very high in sodium, application of gypsum can help move excess sodium off the soil cation exchange and out into the soil solution so it can move downward with water. Another highly effective way to help plants deal with salt is to inoculate with mycorrhizal fungi, which not only helps the plants compete with salt for water, but the fungal hyphae also will move salt out into little "fingers" in the hyphae, and will encapsulate the salt into sealed off hyphal fragments where they cannot pull water away from plants.

Very salt tolerant perennials like tall wheatgrass or forage kochia may be called for in extremely salty soils to bring them back to life and productivity.

Problem Soils: Iron Chlorosis

Iron deficiency chlorosis (IDC) is an issue that plagues many farmers in regions where the soil contains high amounts of calcium carbonate, particularly over much of the western Great Plains. The excess calcium carbonate converts iron from the highly available Fe (2+) into unavailable Fe (3+). Soybeans and sorghum are two crops that are particularly affected by this malady. Many remedies have been tried to help with IDC, but at best they tend to give temporary relief of symptoms.

There may be relief on the horizon. We know that IDC occurs on soils with excess calcium carbonate, but it has been a mystery why it occurred on some soils but not on others with equal calcium carbonate, or why it occurred on one soil in some years but not in other years. It seems that IDC occurs where there is a combination of excess calcium carbonate and free nitrate in the soil. Yes, that is the same nitrate that plants use as a source of nitrogen fertilizer. Understanding why this occurs requires an understanding of the chemical interactions that takes place in the soil immediately surrounding the roots of a plant, called the rhizosphere.

Plants must remain electrically neutral; if they take up a nutrient with a positive charge, they must give off a positively charged ion to maintain neutrality. When plants take up a negative charge, they must give off a negatively charged ion to counteract this charge. This negatively charged ion is bicarbonate, which will convert iron into unavailable forms. Since nitrate has a negative charge and is taken up in large quantities when available in soil, it results in a large amount of bicarbonate in the rhizosphere, and unavailable iron.

To work around this phenomenon, it is necessary to first reduce the amount of free nitrate in the soil, and then provide nitrogen in another form. In the case of soybeans, providing another source of nitrogen is easy, since soybeans are a legume. It is only necessary to use a grass cover crop like rye or oats to soak up the nitrate and convert it into protein in the residue. This protein will later decay and slowly release the nitrogen back. One research trial showed a 40 bushel soybean crop where an oat cover crop was used, compared to a 4 bushel crop without a cover crop.

Sorghum provides a bigger challenge; however, it is possible to use different cover crops to solve the IDC issue. The covers prior to sorghum should be a legume like vetch, sweetclover, or spring field peas. The plant proteins from the legumes will release slowly, and since the legume also fixed additional nitrogen and decays more rapidly, it will be able to add substantial amounts of biologically produced, slow release nitrogen to reduce the amount of fertilizer nitrogen needed.

Another new tool to prevent IDC is inoculating with mycorrhizal fungi, a beneficial fungi that colonize plant roots and then extends root-like structures up to two feet past the root zone that absorb water and nutrients and bring it back to the plants. This is particularly helpful in obtaining immobile nutrients like phosphorus, iron, and zinc, and also function to make the plant more drought tolerant. Spores for mycorrhizal fungi are now available from Green Cover Seed. Manure and compost can also be great aids as they contain nitrogen in organic forms that release slowly just like cover crop residues. They also contain plant available iron that are not readily tied up by calcium carbonate and contain organic acids that make the iron already present in the soil more available. Since IDC usually occurs in spots in fields, these areas should be targeted for manure or compost applications.

Sorghum roots on the right side were treated with MycoApply mycorrhizal fungi. Left side is untreated. The greater root mass of the treated plant help plants avoid the symptoms of iron chlorosis

Finally, don't abandon the old remedies for IDC such as resistant varieties, in-furrow iron, and foliar iron. Though they are seldom sufficient by themselves, in combination with cover crops, mycorrhizal fungi, and manure they can provide a synergistic effect that can recover most of the yield potential lost to IDC.

The bottom line is that there are effective actions we can take to manage IDC, and we no longer have to accept miserable performance of sorghum and soybeans on those areas of our fields susceptible to this condition.

Problem Soils: Compaction

Compaction reduces yields by limiting root growth, but not for the reason most people think. It is assumed that root growth is stopped because the soil is "hard", but the real reason roots do not grow into compacted soil is that there is a lack of oxygen. One reason for this lack of oxygen is that compacted soils have reduced pore space, as well as collapsed passages between pores, so that it is hard for oxygen to diffuse down into the soil. Since yield losses from compaction are caused by a lack of oxygen, and the lack of oxygen is caused by a lack of pore space, it makes sense that the remedy for compaction is to create better pore space in the soil.

Historically, we thought the way to create pore space was with tillage, but pores created by tillage are not stable, and easily collapse when the soil is wetted or driven on. There is no tillage operation which will remedy compaction long term and all tillage will actually make compaction worse, including subsoiling. This surprises many, as a subsoiler has been our "go-to" remedy for decades to break hardpans so roots can go down through it. But that is not the way it works, as subsoiling results in a massive loss of soil organic matter, which makes compaction worse over time.

Photo by Dale Strickler

Compacted soil due to excessive tillage—note the crusting on top and the complete lack of structure in the soil. How much rainfall do you think will infiltrate into this?

So how do you remedy compaction, if not with a subsoiler? The answer lies with biology. Pore spaces are created by the formation of what is called water-stable aggregates, or little soil balls that do not melt away with every rain. Water-stable aggregates are formed when bacteria, fungi, and earthworms give off exudates that glue sand, silt, and clay together into little balls, like popcorn balls are held together with corn syrup. Some of these glues are more durable than others. Bacterial glues are short-term in nature, while the most durable glue is called glomalin, a compound secreted by mycorrhizal fungi. The problem is that most of our cropland soils are now devoid of mycorrhizal fungi, as these fungi must have a live root for a host, and soon starve out with the fallow periods common in our crop rotations. Bacteria, fungi, and earthworms don't just magically appear in cropland soil. These organisms, like any other living thing, need to be fed. Some of them can be fed with manure or crop residue or any other decaying organic material; these organisms are called saprophytes. Leaving crop residue intact on the soil surface also helps prevent future compaction, as it helps hold up hooves and tires. Manure will feed many bacteria and fungi and promote the formation of aggregates. But the real compaction breakers are organisms that live on plant roots and are fed by root exudates. That is why cover crops are an essential link in eliminating compaction; they can keep these organisms that live in the immediate vicinity of the roots (called rhizosphere organisms) alive and thriving when there are no crop roots to maintain them.

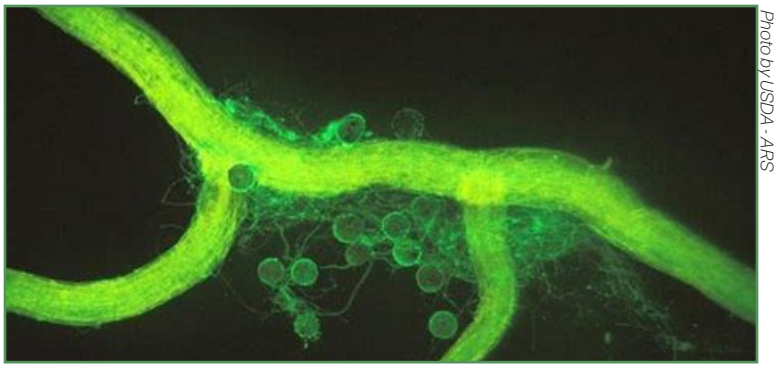


Photo by USDA - ARS

A microscopic view of mycorrhizal fungus growing on a corn root. The round bodies are spores and the threadlike filaments are hyphae. The substance coating all of this is glomalin, revealed by the green dye.

When breaking compaction is the primary goal, any growing plant is better than no plants at all, but obviously some are better than others. When putting together a mix for breaking compaction, it is important to include both species that aggregate soil and species with deep taproots. Here are some of the better species for breaking compaction, keeping in mind that a diverse blend is better than any single species in most cases.

Cool-Season Species

The strong and deep tap root of the **Nitro Radish** has made it a staple item in the Green Cover Seed lineup for quite some time, while the **Smart Radish** is new and features a large number of branches off the main root as well. It also has a higher percentage of its taproot below the soil surface, with less of the root aboveground. **Collards** and **Rapeseed** feature deep taproots like radishes, though not as thick.

Safflower has a very deep taproot and is very drought tolerant. **Phacelia** has a shallow root system but has highly branched surface roots that aggregate the soil surface and allow better infiltration of rainfall and oxygen. **Flax** has an unimpressive root system but is one of the better cool-season mycorrhizal hosts and seems to have a very strong aggregating effect on the soil. **Sweetclovers** (yellow, white, and Hubam) have both strong taproots and high rate of exudates. They are also good nitrogen fixers.

Cereal Rye is probably the best winter cereal for root mass, and it grows at lower temperatures than other cereals. **Black Oats** grow similar to white oats but have a much stronger root system and seem to have a better soil aggregating effect. **Annual Ryegrass** is a true star when it comes to improvement of compacted soils. It has a very dense root system, and it is well adapted to heavy clay soils and poor aeration. Recent research by Murdock in Kentucky has shown that annual ryegrass has root exudates that can actually dissolve fragipans, which are chemically cemented layers in the subsoil. Fragipans are found throughout much of the Southeast US and are very detrimental to crop growth. The research indicated that annual ryegrass could dissolve about an inch of fragipan per year it is grown.

Warm-Season Species

Sorghum-Sudangrass shines among warm-season grasses because it generates an absolutely enormous amount of high energy root exudates that feed soil-aggregating microbes. **Okra** has a very deep taproot and grows quite well in dense soils. **Sunflower** is famous for its deep taproots, but what is often ignored is just how fibrous the roots of a sunflower are in addition to the depth. Pull a sunflower up and you will see just how enormous the root system is. **Buckwheat** has a very small root system but has exudates with strong aggregating ability. **Sunn Hemp** has a more vigorous taproot than most other summer annual legumes.

Perennial Species

Chicory has a very deep taproot and performs well on dense soil.

Plantain seems to grow exceptionally well on soils so compact no other plant seems to grow at all.

Eastern Gamagrass and **Reed Canarygrass** have a specialized root tissue that allow them to grow on extremely dense soils. **Tall Fescue** and **Perennial Ryegrass** are known for their ability to grow well on compacted and heavy clay soils. In drier areas, many wheat grasses can grow in compacted soils.

Photos by Dale Strickler

Left: Highly compacted, extremely dense soil with no roots penetrating below 18 inches. Note the gray color due to lack of carbon and lack of oxygen being able to move into the soil profile. Right: Same field after three years of Eastern gamma grass production. Compaction layers are gone, roots are penetrating deep, oxygen is moving freely, and productivity and infiltration rates are very high.

Problem Soils: Heavy Clay

Clay soils are a blessing and a curse! Clay has a very high ability to hold water and plant nutrients, much higher than sand or silt. However, its small pore sizes restrict the movement of air and water into the soil leading to low infiltration and limited root depth. This combination of poor infiltration and poor root depth makes clay soils susceptible to water deficiencies, even in high rainfall regions. Clay soils are also sticky when wet and rock hard when dry. In the past, conventional wisdom was to intensely till the soil to make it loose; however, the result was the destruction of soil organic matter (SOM) and soil aggregates, making the situation even worse.

Some say that no-till won't work on heavy clay soil. The truth is, tillage doesn't work very well either. The best remedy for clay soil is to have plants growing as much as possible which will add SOM and feed soil microbes that build aggregation. Forming the clay into little balls (aggregates), around which air and water can freely move, is the ultimate solution to improving clay soil.

We used to think the best way to increase SOM was to bring in manure from somewhere else, but this is an expensive process. What we have discovered recently is that SOM is best formed by two agents: microbes that feed on root exudates and mycorrhizal fungi, the benefits of which have been previously described. It is essential for the growth of both mycorrhizal fungi and rhizosphere microbes to maintain living roots for as many days of the year as possible. This can be achieved by growing perennial crops or integrating cover crops between the cash crops in a rotation. The cover crops and perennial crops that tend to work well on heavy clay are the same ones previously listed that do well in compacted soils.

Photo by Keith Berns

Growing roots and soil biology cause soil aggregation which in turn makes high clay soils much more productive!

> *"Stopped in today and got my seed. Please thank your staff for me. Never have I met a better group of people. Absolutely amazing. Friendly, helpful, and just a pleasure from the minute we walked in the door. Can't wait to come back—I didn't want to leave."*
>
> Scott M, Canada

Doug and Anna Crabtree's farm rests on more than 2,000 acres in northern Montana, and it is a model of how cover crops can be a foundation of pollinator and beneficial insect management. Like many farmers, their approach to cover cropping began with an interest in soil health and quickly grew to encompass much broader goals as they recognized the additional benefits cover crops could provide. "We want to implement pollinator conservation at the field-level scale," Doug says. "Anyone can create a small wildflower strip, but as we scale up, we need conservation areas distributed across the entire operation." While the Crabtrees have established permanent native wildflower strips around many of their fields to provide a skeleton of habitat throughout the farm, extensive cover crop rotations provide the muscle that makes their operation a rich landscape for bees and other beneficial insects. This commitment to cover cropping is having clear and positive impacts on crops such as flax, sunflower, and safflower. A farm's ability to support its own pollinator community provides biological security, and the Crabtrees have never needed to bring honey bee hives onto the farm for pollination.


Photo by Julie Birky

Basic Pollinator Ecology

Honey bees and wild bees alike are considered important agricultural pollinators, and both groups of bees share many of the same habitat requirements necessary to thrive. Both require reliable and abundant pollen and nectar resources throughout the growing season. In addition, bees require protection from pesticides. While large doses may be directly lethal to bees, smaller doses can result in sublethal impacts, such as reduced reproduction or foraging. Interestingly, research suggests that diverse pollen and nectar resources may help improve the overall health of bees and increase their chances of detoxifying low doses of some pesticides. Wild bees also need undisturbed areas for nesting, and the undisturbed soils of a cover crop can provide this. Flowering cover crops can support the habitat requirements of bees through pollen and nectar resources to maximize their health and reproductive potential, an abundance of nectar to produce surplus honey, a refuge from insecticides, and enhanced nesting opportunities for wild bee species.


Photo by Dirceau Gasson

Other Beneficial Insects

The natural enemies of crop pests that sometimes inhabit farms include a diverse range of predatory beetles, aphid-eating flower flies, lacewings, small solitary parasitic wasps, and many others. In addition to preying upon crop pests, most of these predatory and parasitoid insects either need, or benefit from, alternative food sources during at least one stage of their life. In some cases, that alternative food source is nectar or pollen. Consequently, like pollinators, many of these natural pest enemies also benefit from flowering cover crops. An increase in beneficial insects brought about by a mix of annual buckwheat, lacy phacelia, and sweet alyssum resulted in fewer pests. In other cases, cover crops can support beneficial insect populations even when they do not flower. Some predators and parasitoids do not feed on nectar and pollen, but rather need a continuous supply of prey insects to maintain their populations. So when cash crops are absent, non-flowering cover crops can support pests to the extent that they become a stable food source for beneficial insects.


Photo by Dirceau Gasson

For example, ground beetles, which are generalist predators of slugs, caterpillars, and grasshopper eggs, can be sustained by leaving some areas unmowed or by creating a "beetle bank" of perennial grasses outside crop fields. Beetles can overwinter in this augmented habitat and their prey can breed in it. Thus, these grassy refuges can keep the beetle population high by providing both habitat and a food source outside the cropping period. Similarly, even if prey insects found in cover crops are not pests of your cash crops, they can still be an important food resource for predator and parasitoid insects that will switch their prey preference once cash crop pests become available. Finally, like pollinators, predatory beneficial insects need protection from insecticide applications and vegetative structures for egg-laying or overwintering. Well-managed cover crop systems can help meet these habitat requirements.

The plants that best fit your needs will vary by location and purpose. Different cover crops have different strengths. Flowering broadleaf species are a must when selecting

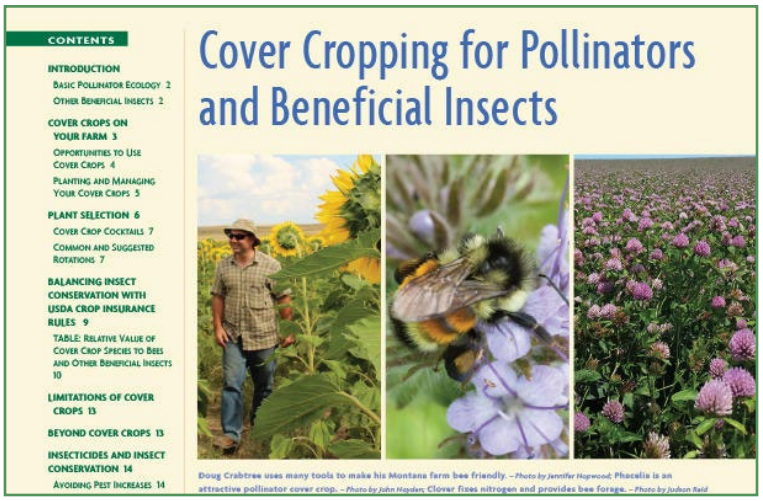
cover crops for pollinators. Grass cover crops do not provide nectar and their pollen typically has lower protein content than the pollen of broadleaf plants, making them only marginally attractive to bees. A flowering plant/grass blend may be an ideal solution in situations where a grass crop is needed to achieve other management priorities, such as preventing nutrient leaching. You have more flexibility when selecting plants in support of predator and parasitoid insects for pest management, with certain grass cover crops supporting alternate prey (such as aphids) to help sustain the beneficial insects when cash crops are absent. Avoid cover crops that serve as alternate host plants for crop diseases and those that support large numbers of crop pests. An alternate host is another species, different from the cash crop, which serves as a reservoir for the pest or is necessary for the pest to complete its life cycle. For example, if you are growing a brassica vegetable crop, do not cover crop with another brassica, as it would support similar pests. However, cover crops that support low levels of crop pests may be valuable in some cases, as they can provide a consistent food source for beneficial predators.

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

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

This diversity can really pay off. Using a SARE grant, a researcher in Florida found significant differences in wild bee abundance and diversity based upon the number of crops present on a farm. At one end of the spectrum, the farm with the fewest number of bees (5 species) grew only two crops and mowed directly up to the field edges. The farm with the greatest abundance of bees (14 species) grew nine crop species and maintained open, unmowed buffer areas around the farm. Multi-species cover crop mixes are a relatively simple way to expand plant diversity on a farm, with benefits to bee abundance and diversity.

This is an excerpt from an excellent publication from SARE entitled "Cover Cropping for Pollinators and Beneficial Insects". If you are interested in this topic, we encourage you to download the entire 16 page bulletin from www.sare.org.



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Cover Cropping for Pollinators and Beneficial Insects

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

As if Ryan and Jennifer Speer do not have enough chaos in their life, they are adding chaos to their garden! These Sedgwick, KS farmers are prime examples of big-hearted folks who are donating a small portion of their farm to producing something for others in the form of a chaos or Milpa garden!

The Milpa system is a traditional multi-species cropping system originally designed by the Mayans and still used throughout Mesoamerica. Traditional Milpa gardens use the "three sisters" concept with maize (corn), squash, and beans, but with the addition of many other species for diversity in the system. This practice continues to this day with some fields planted to a Milpa continuously for 4,000 years and is still fruitful.

Photos by Ryan Speer

"A typical garden is fairly high maintenance but the Milpa garden is plant it and forget it," notes Ryan. Jennifer, who is also a member of their local Food and Farm Safety Council, stresses that they were "looking for a way to get fresh fruits and vegetables to people in our county who did not have access to them." Since there are no neat, straight rows, harvesting is hard work. "It's kind of like a scavenger hunt. The yellow squash and pumpkins show up really nice but the green cucumbers are really hard to see in there. When the Milpa really starts to produce, we'll start getting 2-5 laundry baskets of vegetables every other day. So we have to come out here for 2-3 hours every other night and load them up and deliver to the food bank," comments Ryan.

The Speers learned about the Milpa concept by watching the partnership between Green Cover Seed and the Farm to Food Bank project in Oklahoma. Beginning in 2017, Green Cover Seed donated Milpa garden seed to several regenerative farmers throughout Oklahoma who partnered with the Regional Food Bank of Oklahoma. Each participant planted several acres of diverse Milpa gardens. The simplistic beauty of the system is that all the seeds were mixed together and drilled with a regular grain drill, turning a small field into a large garden with very low labor inputs. Green Cover Seed provided the seed mixes which included fresh greens (turnips, collards, mustard), root vegetables (radish, turnips), legumes (cowpeas, mung beans, black beans), and vine crops (squash, melons, cucumbers, pumpkins). The gleaning efforts were a true community effort with members from various community groups all pitching in to help feed their community.

In 2017, about 6,800 pounds (about 5,440 meals) of fresh, healthy fruits and vegetables were donated from these gardens to the Regional Food Bank of Oklahoma. The Milpa gardens not only provided fresh and healthy food to these local communities, but helped build community relationships as well. These gardens also served as a diverse cover crop mix to help improve soil health, water quality, and habitat for pollinators and wildlife on these farms.

At Green Cover Seed, we believe that with healthy soils we can grow healthy plants, which will produce healthy food, which will build healthy people, families, and communities. With that in mind, we will donate an acre of highly diverse Milpa garden seed to anyone who is working with their local food bank or resource center to help feed and build their local community! So for the benefit of your community, consider adding a little bit of Milpa to your already chaotic life!

"Regenerative Agriculture is an understanding... that one must work with nature instead of against her."

Gabe Brown

QUORUM SENSING AND AUTO INDUCERS IN THE SOIL MICROBIOME

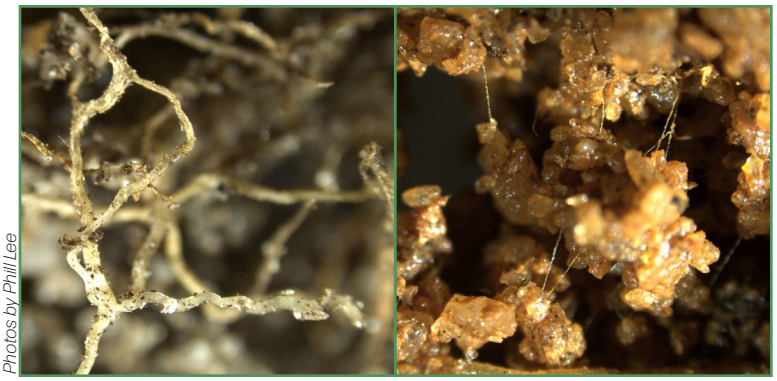
One of the true rock stars in the soil ecology world is our good friend Dr. Christine Jones. She is an internationally renowned and highly respected groundcover and soils ecologist and has taught here at our farm several times in recent years. She has a wealth of experience working with innovative landholders to implement regenerative land management practices that enhance biodiversity, increase biological activity, sequester carbon, activate soil nutrient cycles, restore water balance, improve productivity, and create new topsoil.

In human society, a **quorum** is the number of members of an organization that must be present in order for decisions to be made and business to be transacted. In the microbial world, the term **quorum sensing (QS)** refers to **density dependent coordinated behavior** that regulates gene expression in the microbial population and/or in the host plant or animal.

Quorum sensing was first described in the 1960s in relation to the expression of bioluminescence in the marine bacterium *Vibrio fischeri*. When free-living in the ocean, *V. fischeri* is non-luminescent, but when populations reach a critical population density they "shine"... but only in the dark. The bacteria know "how many" of them there are—and they also know that it's dark.

Microbes can't see, think, or hear. But by means of chemical signals, called auto-inducers, they have the capacity to detect how many others are in their vicinity—both of their own species and of other species. In the last decade, research into quorum sensing has grown exponentially. It is now recognized that quorum sensing is utilized by bacteria, archaea, fungi, and viruses in all habitats—in water, on land, in plants, on plants, in the soil, and in animals and humans.

Social insects like ants and bees also use signals to communicate. A single bee behaves very differently to a colony of bees. Similarly, a single bacterium behaves very differently to a colony of bacteria. And even a colony of one kind of bacteria behaves very differently when it is the only colony—compared to when there are multiple colonies of many kinds of bacteria.



Photos by Phill Lee

Left: Crops seeded into chemically-fallowed soil in the presence of high rates of N have bare roots. In the absence of a microbial quorum there is no protection from pests and diseases and no soil building.

Right: The roots of crops direct drilled into diverse cover without the use of high-analysis fertilizers support a protective, soil-building microbial quorum.

Quorum sensing in the soil microbiome enables multi-species crops and pastures to function more effectively than monocultures. Once the diversity of plants and hence the diversity of functional groups of soil microbes reaches a certain threshold—or quorum—everything changes. The microbial community begins to function as a coordinated "super-organism" and can perform tasks that individual microbes cannot achieve alone. The lights come on, not unlike the bioluminescent marine bacteria that suddenly shine brightly in a dark ocean.

Quorum sensing also helps explain how biostimulants improve plant health, even at very low concentrations. The biochemical signals mimic plant and microbial diversity, resulting in the production of growth stimulating and plant protection hormones.

Disease-causing organisms use quorum sensing to express virulence and pathogenicity. The good news is that once the configuration of the signals has been determined, they can be scrambled and rendered ineffective by a process termed "quorum quenching" (QQ). Quorum quenching is proving to be more effective than antibiotics and fungicides, which kill everything, good or bad.

In soils, both QS and QQ are important for the function and resilience of plant communities, not only in the face of biotic stresses (e.g. pests and diseases) but also in regards to promoting health, abundance and resilience in the face of abiotic stress (such as drought, frost, and nutrient deficiencies).

There is much to be gained by applying our understanding of quorum sensing in the agricultural space. QS is the only process that adequately explains the extraordinary results (such as abundant nutrient availability and enhanced drought tolerance) observed once plant diversity—and hence microbial diversity—each a critical threshold, or tipping point.

The flip side to quorum sensing is that when there are not enough microbes to form a quorum, nothing happens. No matter whether it is in the human or animal gut—or in the soil—when microbial populations do not attain a quorum some very important genes (that plants, animals, and people require for immunity, for example) get switched off. The lights go out... which is precisely what's happening today in human, animal, plant and soil health.

We need to figure out how to turn the lights back on... and fast.

It comes as a surprise to many to learn that plants and microbes constitute 99% of the biomass of life on earth. Things we can readily observe, like people, animals, birds, reptiles, insects, and fish, make up the remaining 1%.

Collectively and cooperatively, plants and their associated microbes underpin the functioning of all major ecosystems, including soils. Improving our understanding of these interactions is key to restoring the productivity and resilience of agricultural land, enhancing the quality of the food and fiber produced, reducing the need for inputs, increasing farm profit and supporting human health and wellbeing.

Photo by Doug Garrison

Root hairs and the fungal network of a corn root that will feed the microbes in the surrounding rhizosphere.

Although the biomass and power of microbes is immense, like all other life forms they require an energy source. For most microbes of agricultural significance, this energy comes from the sun. The liquid carbon pathway requiring the presence of green, actively photosynthesizing plants is the principal means by which light energy is transformed to biochemical energy and transported to the soil ecosystem. Within soil, some of the liquid carbon is distributed via common mycelial networks, linking plant roots with distant microbial communities while the remainder supports trillions of microbes in the rhizosphere. Some intriguing symbiotic relationships take place here, including microbivory, or rhizophagy, in which microbes are attracted to and engulfed by actively growing root tips. After being stripped of their nutrient loads, microbes exit via root hairs to start the cycle again.

Some forms of microbes are also able to freely alternate between a soil phase and an endophytic (inside the plant) phase. These beneficial microbes can assist with the transfer and assimilation of nutrients, confer pest and disease resistance and improve tolerance to abiotic stresses such as frost, drought and salinity. The movement of microbes from the soil into plant roots (and from there into stems, leaves, flowers and seeds) is termed **biological induction**.

Common mycorrhizal networks, microbivory and biological induction are but a few of the extraordinary symbiotic relationships that exist between plants and microbes. Many more are yet to be discovered. The question then becomes—how do we increase the number and biomass of the beneficial microbes that are able to assist the growth of plants?

The answer is—more plants!! Or more correctly, a greater diversity of plants, growing together in communities.

We need to be mindful that in the not-too-distant past, the world's prairies, grasslands, savannas, and meadows were extremely diverse, with 300 to 500 plant species thriving together in mixed communities. At least 60% of the species were forbs. Plant diversity increases microbial diversity, assisting the sequestration of soil carbon, which in turn improves soil health, enhances the availability of nitrogen and phosphorus, improves soil water-holding capacity and water-use efficiency and enhances plant productivity. These beneficial effects are additive and every kind of plant counts—the more different types of plants you put together, the better it gets.

Photo by Christine Jones

Jim Harbach (top), Schrack Farms, Loganton, PA, watches as Peter Donovan performs a water infiltration test in a multi-species cover including buckwheat, sunflowers. sorghum, forage collards, non GMO soybeans, Persian clover, radish, canola, and subterranean clover. Infiltration rates are very high due to the diverse cover mix.

Fortunately, it is not necessary to restore several hundred species of plants to agricultural land to achieve soil health benefits. Relatively simple cover crop mixes can go a long way toward improving soil function, provided there is a diversity of plant functional groups. It is beneficial if diverse cover crop and forage crop plantings can be accompanied by a biostimulant, preferably on the seed, but at the very least in furrow or as a foliar applied at or soon after emergence. High analysis fertilisers disrupt the plant-soil microbiome and should not be placed on, under, or near seeds - or indeed, in contact with the soil. Other harsh chemicals, such as herbicides, insecticides, and fungicides also disrupt the intricate relationships that exist between plants and microbes.

Remember, the soil is a living thing. Our quality of life depends on how well it functions.

By Christine Jones, Ph. D

A native of Australia, Christine has rapidly become one of the most sought after Soil Health speakers in the world and has been wildly popular on the United States Soil Health speaking circuit. We count it a blessing to call her a mentor and a good friend of Green Cover Seed.
For further information, visit www.amazingcarbon.com.

Nitrogen is a component of protein and DNA and as such, is essential to all living things. Prior to the Industrial Revolution, around 97% of the nitrogen supporting life on earth was fixed biologically. Over the last century, intensification of farming, coupled with a lack of understanding of soil microbial communities, has resulted in reduced levels of biological activity on agricultural land and an increased application of industrially produced forms of nitrogen.

Impacts of Inorganic Nitrogen

Much of the nitrogen currently used in agriculture derives from the Haber-Bosch process, in which atmospheric nitrogen is catalytically combined with hydrogen to produce ammonia under conditions of high temperature and pressure. This process uses non-renewable resources and is energy intensive and expensive. Globally, over $100 billion of nitrogen fertilizers are applied to crops and pastures every year. Between 10-40% of the applied N is taken up by plants while the other 60-90% is leached into water, volatilized into the air or immobilized in soil. The application of high rates of inorganic nitrogen in agricultural systems has had many unintended negative consequences for soil function and environmental health. Above ground, plant growth often appears "normal", hence the connection to failing soil function may not be immediately obvious. But underneath, our soils are being destroyed.

Biological Nitrogen Fixation (BNF)

Fortunately—thanks to some "enzymatic magic"—atmospheric nitrogen can be transformed to plant-available forms by a wide variety of nitrogen-fixing bacteria and archaea—for free. The ability to fix nitrogen is not limited to bacteria associated with legumes. Recent bio-molecular research has revealed a dizzying array of free-living and associative nitrogen-fixing bacteria and archaea across a wide range of environments. Their abundance is much greater in soils where diverse living groundcover is present throughout the year, compared to soils that have been monocropped or left bare.

Photo by Christine Jones

N fertilizer placed below the seed inhibits the formation of rhizosheaths on the roots of cereals. Note healthy rhizosheaths above the seed (away from the N).

Photo by Trey Archer

Rhizobia bacteria form N fixing colonies or factories on the roots of legume plants, like this sunn hemp. These tiny workers split the atmospheric di-nitrogen molecule and transform the N into a form that plants can use!

The Liquid Carbon Pathway

Carbon and nitrogen are essential to plant growth and integral to soil function. A massive 78% of the earth's atmosphere is composed of dinitrogen (N2). Carbon dioxide (CO2), on the other hand, is a trace gas, currently comprising only 0.04% of the atmosphere. The incorporation of both carbon and nitrogen into stable soil organic complexes via photosynthesis and the liquid carbon pathway effectively transports these vital elements from the atmosphere to the soil. The plant's requirement for biologically-fixed nitrogen drives this process. Liquid carbon is transferred to complex microbial communities within rhizosheaths and root-supported aggregates, where simple carbon molecules are transformed to highly stable humic polymers, composed of biologically fixed carbon, nitrogen, bacterially-solubilized phosphorus and soil minerals.

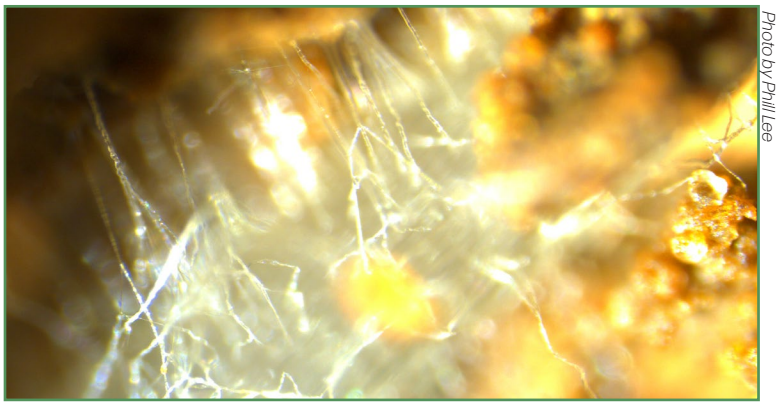


Photo by Phill Lee

Saprotrophic and symbiotic fungi transfer "liquid carbon" from roots to free-living N-fixing bacteria and archaea within the rhizosheaths of plants grown without N.

Although mycorrhizal fungi do not fix nitrogen, they play a vital role in the nitrogen nutrition of plants by transferring energy, in the form of liquid carbon (also called photosynthate), to associative and free-living nitrogen-fixing bacteria. The acquisition and transfer of both organic carbon

and organic nitrogen via mycorrhizal pathways is highly energy efficient, closing the nitrogen loop, reducing nitrification, denitrification, volatilization and leaching.

Enhancing the Liquid Carbon Pathway

We can utilize our understanding of the liquid carbon pathway to restore natural fertility to agricultural land. Enhanced carbon flow to soil—via plant root exudates—not only supports the biological fixation of atmospheric nitrogen, but also activates the vast network of microbial communities essential to the provision of minerals, trace elements, vitamins and hormones required for plant tolerance to environmental stresses such as frost and drought and resistance to insects and disease. Higher micronutrient densities in plants also translate to improved nutritional value of food. However, if nitrogen is supplied in an inorganic (fertilizer) form, it will short-circuit the liquid carbon pathway. As a result, plant mineral densities fall and immune function is reduced.

Photo by Jimmy Emmons

Plant root exudates leaking out to feed soil biology.

Getting the Basics Right

It is now recognized that plant root exudates make a greater contribution to the formation of stable organic complexes within the soil than does the above-ground biomass. But here's the rub. The microbes essential to the stabilization of carbon require living groundcover and are inhibited by high rates of inorganic N. Hence biological nitrogen fixation and humification are rare in agricultural systems where heavily N-fertilized crops are rotated with bare fallows. Further, it has been shown that up to 80lb N/acre can be volatilized and lost from bare fallows due to denitrification in warm summer months. If green plants are present, this N can be taken up and recycled, preventing irretrievable loss. When soil is bare there is no photosynthesis and very little biological activity. Bare soils lose water, carbon and nitrogen, nutrient cycles become dysfunctional, aggregates deteriorate, structure declines and water-holding capacity is reduced. The maintenance of bare fallows—or the use of high rates of inorganic N in crops or pastures - or worse, both—results in the uncoupling of the nitrogen and carbon cycles that have functioned synergistically for thousands of years.

Weaning Off Nitrogen

The activities of both symbiotic and associative N-fixing bacteria are inhibited by high levels of inorganic N. In other words, the more nitrogen fertilizer we apply, the less N is fixed by natural processes. For this reason it is vitally important to wean your soils off high rates of inorganic N—but please do it slowly. Microbial communities generally require around three years to adjust. Nitrogen inputs can be reduced 20% the first year, 30% the second year and a further 30% the third year. In subsequent years, the application of small amounts of inorganic N will help to prime the natural nitrogen-fixing processes. In addition to weaning off high rates of inorganic N, aim to maintain as much diverse year-round living groundcover in crops and pastures as possible.

There is increasing recognition of the fundamental importance of soil microbial communities to plant productivity. Many biological functions are compromised by commonly used agricultural practices but fortunately redesign of farming practice is not difficult. The five basic principles for regenerative agriculture discussed earlier in this Resource Guide have been proven to restore soil health and increase levels of organic carbon and nitrogen. From these, farmers and ranchers can build an integrated land management package that suits their individual property and paddock needs.

More and more farmers around the world are discovering how to restore natural topsoil fertility by moving away from bare fallows to biodiverse year-long green plant cover, coupled with appropriate livestock management and reduced applications of inorganic nitrogen. Improvements to soil function deliver benefits both on-farm and to the wider environment.

Photo by Christine Jones

Healthy rhizosheaths on 8-week cereal rye seeded early fall without N.

By Christine Jones, Ph. D

A native of Australia, Christine has rapidly become one of the most sought after Soil Health speakers in the world and has been wildly popular on the United States Soil Health speaking circuit. We count it a blessing to call her a mentor and a good friend of Green Cover Seed.

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In the past decade we have learned a great deal about plant species, their use as cover crops, and how they can create healthier soils. We have learned that soil improvement comes primarily from soil microbes, and that one of the primary contributions of cover crops is to feed soil microbes. We actually know very little about those soil improving microbes; even the best soil microbiologists only understand a small fraction of what goes on in the soil (see pages 46-51 for more biology information). We may not know what individual microbes are doing and how to manage them on a species by species basis, but we can apply some general principles that encourage the growth of microbes in general and to consider using microbial inoculants when it makes sense.

There are literally thousands of companies that sell "bugs in a jug" products. Most of these products have some legitimate value, but some have such low concentrations that they can't make a difference. Most commonly, though, the soil has simply not been managed to provide good microbial habitat. It is important to understand that it is impossible to simply inoculate your way to soil health, but we must create the conditions that promote healthy microbial populations - which happen to be the same as the principles of soil health: limited soil disturbance, soil cover, year-round living roots, plant diversity, and livestock integration. Microbial inoculation will provide the most visible benefits on degraded soils that are having soil health principles applied.

At Green Cover Seed, we are constantly evaluating and exploring biological inoculants and any inoculant we choose to put on the market must provide more dollars of benefit than it costs. Our offerings will change as we learn more about which products provide clear economic benefit and fit well with the use of cover crops. We are always eager for our customers to try out new biological products and give us their honest feedback after doing due diligence to accurately measure value.

In addition to rhizobium inoculants for legumes (which few people question the value of), we offer several microbial inoculants which we feel are useful.

Photo by Brett Peshek

Mycorrhizal fungi (MF) are fungi that live on and within plant roots in a mutually beneficial relationship, and extend root -like structures called hyphae that reach out as far as 18 inches past the root zone to obtain water and minerals for the host plant that plants alone cannot access. MF also exude a substance called glomalin, a powerful soil aggregating compound that is more persistent than other forms of soil organic matter. MF are present in all natural ecosystems, but are usually lacking or in very low numbers in tilled or fallowed cropland, because MF need a living host root to live. It is important to realize that MF are not a magic potion, but they can enhance yield by helping access additional water and nutrients. The best responses to inoculation will result when natural populations of MF are lacking, as in a field with a history of tillage or long fallow periods, and when moisture or minerals are lacking. Heavy clay soils show the most improvement over time from the exuded glomalin. Crops that respond best on a "dollars returned for dollar invested" basis are perennial crops like alfalfa and new seedings of perennial grasses, as the MF lives as long as the host plant, so a single inoculation can last several years. Another high return scenario from a single inoculation is to inoculate at the beginning of a crop rotation featuring continuous living roots from a sequence of cash crops and cover crops.

Photo by Wendy Tahari

Wendy Tahari, one of the top soil microbiologists, also points out that MF feed and support other soil microbes that benefit the crops. When systems are managed to support MF, other beneficial organisms increase as well, and less fertilizer and fewer inputs are required, as the diversity that comes along with good management promotes plant health while creating competition that helps to keep pests under control. Most agricultural chemicals have a negative impact on soil microbes, so save them for the real emer-

gency. Constant use 'just in case' is what leads to pesticide resistance, which means when you REALLY need to get something under control, nothing seems to work very well. Good management results in healthy soil and that is the best crop insurance in the world. "Don't work your soil, let the soil work for you!"

Another promising product is our Bi-Azo inoculant, a mixture of Azotobacter and Azospirillum, two free-living nitrogen fixing bacteria that live in the rhizosphere of many plant species, including non-legumes like grasses. Scientific research has demonstrated that in situations where the soil is lacking in nitrate, these two bacteria will fix small amounts of nitrogen in the root zone of non-leguminous plants (scientific literature indicates a range of 0-80 pounds of N per acre, with most reports around 20-40 pounds of N). They do not fix nitrogen when there is ample available nitrogen in the soil. These two bacteria are common in many regions around the world where nitrogen fertilizer is unaffordable or hard to transport for small farmers, but not used much in the US where the common practice is to apply heavy amounts of nitrogen fertilizer to crops. However, since most cover crop mixtures of grasses and legumes are not fertilized with nitrogen, these mixtures may benefit from Bi-Azo inoculation. Often summer annual grasses like sorghums and millets are not fertilized for fear of creating toxic levels of nitrates so Bi-Azo can provide plants with small daily amounts of ammonium nitrogen that will not spike nitrate levels in plants. Since the cost of Bi-Azo is only a few dollars per acre, it takes only a small benefit for it to pay.

Another inoculant that has a very high benefit to cost ratio is an application of our HyprGrow compost extract. Green Cover Seed has recently invested in Elevate Ag, a new venture that is producing a patented compost extract product (HyprGrow) and we can now offer this as a seed applied inoculant on cover crop seed or as a liquid product for farmers to apply in-furrow or as a foliar application on cash crops or cover crops. Compost extract is made by leaching water through a compost made in a specific manner to culture beneficial microbes. Compost extract is a liquid teeming with billions of microbes and auto-inducers (see pages 44-45) and can be applied at a very low cost. Organic farmers and gardeners have used compost extracts for decades and have seen good results. Science is now corroborating these positive results and beginning to unravel the microbial mysteries behind the results.

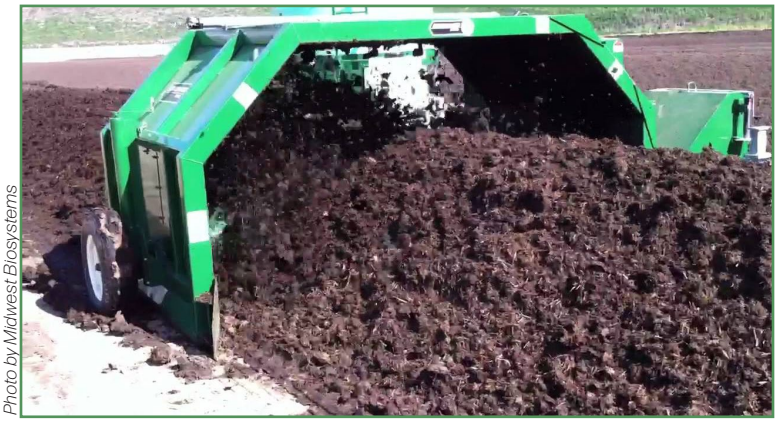
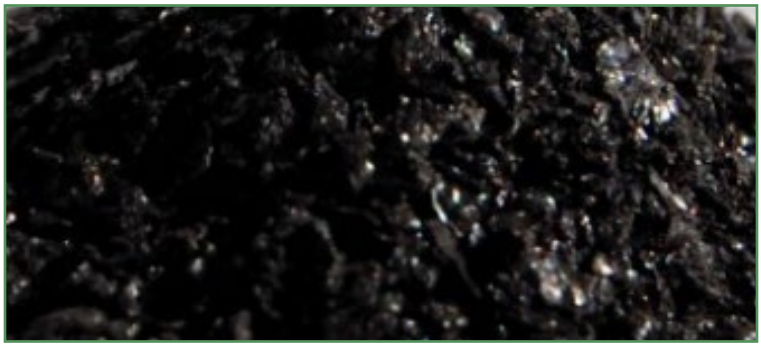


Photo by Midwest Biosystems

HyprGrow is extracted from a high quality compost that is made with a patented process that keeps the biology alive longer. The liquid extract can be used as a seed treatment, starter fertilizer, or foliar applied to the plant.

Elevate Ag also offers a full line of humate products. Humates are the natural result of the humification of organic matter over thousands of years and are complex carbon molecules resulting from biochemical reactions. Humates are a critical component of soil fertility and plant nutrition and are a rich source of energy and beneficial bacteria which aid overall plant health. Other benefits of humates include enhanced fertility uptake, improved water holding capacity, improved seed germination, and increased root growth. We have also been adding humates to our liquid fertilizer as a stabilizing agent. The HyprGrow extract contains humates and Elevate Ag's line of Halo products are humates that can be used right at the farm as a fertilizer or seed amendment.



Elevate Ag is owned by Green Cover Seed and five partners from Kansas. This innovative biological company holds a patent on a process to make a better compost product. Elevate Ag also offers a full line of humic products, including humic acid and humate products that can be added to liquid fertilizer or as a seed treatment. Elevate Ag is committed to being a leader in innovation in practical and affordable biological solutions for farmers. Go to www.elevateag.com for more information.

elevate AG
Recapturing A Land Of Milk & Honey

This article is a tribute to the late Matt Hagny who was tragically killed in a rock climbing accident in 2019. Matt was a driving force in the formation of No-till on the Plains and was extremely influential in no-till adoption in KS, OK, and NE. This article is condensed from a full length article first published in No-till on the Plains Leading Edge Magazine in 2003. As you will see, Matt was far ahead of his time with this insightful article from 17 years ago.

The complete article can be found on our website by searching "Leveraging Biology".

Think of your fields as ecosystems where nature isn't easily confined or excluded and life is quite resilient. Instead of focusing on wiping out the population of pesky organisms, we should instead be looking to avoid the confrontation, or at getting the suppression some other way. "Brute force" technology generally fails to subdue biology—the technology is very costly, plus, the target often evades the control measure and the side-effects are sometimes unanticipated and unpleasant. We need to look for ways to manipulate the system to get what we want—to find those places where we can exert small pressures and produce big changes, to leverage biology in our favor.

Hired Guns

One of the most visible ways of leveraging biology is using beneficial organisms to control harmful ones—nurture your allies and let them fight your wars for you. Some farmers purchase and release beneficials in their fields to boost numbers, but why not just ensure that their numbers are high from the start? This is what can occur in a well-managed system following soil health principles. Keeping crop residues on the surface holds moisture and creates an environment suitable for these beneficial organisms, ensuring their population builds early and stays strong. Lady beetles and lacewings are often given most of the credit, but spiders actually do much of the work when it comes to controlling damaging insects.

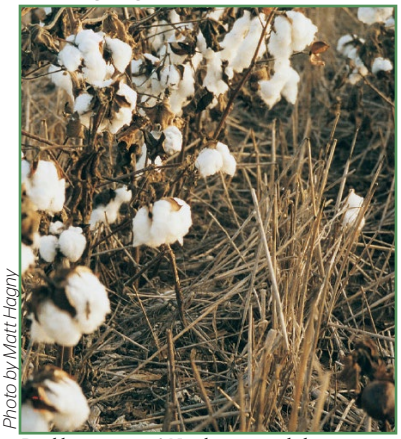


Photo by Matt Hagny

Double crop cotton? No, this was seeded into a cover crop of wheat, which was killed while the cotton was seedling. The evidence is convincing: cover crops ahead of cotton build populations of spiders and lady beetles, which works wonders for controlling the thrips, fleahoppers, aphids, and bollworms that show up later. Biocontrol for free!

In cotton, for example, spiders are very important for controlling fleahoppers. Establishing a good beneficial population early involves providing habitat and a food source for them, by keeping residue on the surface (or, better yet, a growing crop) and not spraying insecticides. Spiders and lady beetles will feed on a wide range of other organisms, and can establish populations long before damaging insects ever show up—but these beneficials can't prosper in the barren wasteland of a tilled field. However, a winter cover crop killed just before cotton emergence (or early postemerge) really builds the spider and lady beetle population early, which will typically control thrips, aphids, and bollworms. Similar measures keep corn borers at bay—a good supply of lady beetles will devour most of the eggs and larvae, although it is strictly a "numbers game." Other insect problems can also be avoided with good management. Corn rootworm can often be handled by proper rotation, which is basically deprivation of a host.

A Jungle Out There

What about weeds? They do seem to "disappear" when left on the soil surface, which is well documented (see Randy Anderson's data). Some of this is biology (predation), and some is just pure weathering and chemical degradation. Leaving the weed seeds on the soil surface maximizes these mechanisms. Temperature fluctuations and sunlight are strongest on the surface, as well as the most feeding by ants, beetles, crickets, etc. The greatest amount of biology is almost always in the duff layer on the surface and the half-inch of soil underneath and the same microbial and fungal feeding that degrades stubble also works to destroy weed seeds. Generally, most of these decay processes are accelerated under crop canopy conditions as the humidity is kept higher.

Another component of biological control of weeds is competition from your crop. Sunlight and nutrients are limited in supply, not to mention pure physical space to grow so make the crop (or cover crop) as competitive as possible. Of course, rotations are key to effective biological control, as crops will be competitive at different times of the year. Beyond competition for resources, cover crops may even actively suppress weed growth with "chemical warfare"—

Photo by Keith Berns

emitting compounds to limit the growth or even kill neighboring weeds (the first herbicides were used by Nature!). This chemical warfare, or allelopathy, is only beginning to be understood, yet is another biological tool to be used to our advantage.

Unhealthy Living

Diseases aren't quite as obvious as insects and weeds, and may not receive as much attention, but they're still in the realm of biological control. Disease-causing organisms all have dormant stages that can survive for some time until coming into contact with a new host. Interfering with disease infection and/or progression in plants can involve several mechanisms, such as reducing the levels of these resting stages in the environment (soil or air), disrupting their "sensing" of the proper host, or enhancing the plant's defense mechanisms. Reducing inoculum load may involve longer intervals of nonhost plants, or other ways of increasing attrition of the resting structures—time, chemical weathering, and biological predation are your allies. Having a crop or cover crop growing in the field often creates conditions that either accelerate the death of these enemies, or that actually fake them out of dormancy (only to find themselves trying to infect a non-host species, or one that isn't the cash crop).

This is perfectly illustrated by a study of white mold levels in soybeans as affected by cover crops, conducted by Craig Grau of University of Wisconsin. Grau suspected a biological solution might work to combat white mold. In a no-till corn/soybean rotation, cover crops of wheat, oats, and barley (all non-hosts) grown ahead of soybeans were compared to check strips of no cover crop. Over multiple years and locations, white mold incidence in the soybeans was significantly reduced by all three cover crops, and the white mold resting structures had indeed broken dormancy in all of the cover crop strips, but not in the check strips.

Underground World

The roots of your crops grow in a unique world—an ecosystem largely unseen and unexplored by humans. The plants that are allowed to grow in your fields will radically alter the ecosystem every year. Every plant has a unique "signature" of root exudates (substances leaking from roots), and these exudates may attract or discourage certain species among the diversity of bacteria, fungi, nematodes, and other organisms in the soil. Those species often vie for root exudates as food sources, to the extent of bacteria that produce antibiotics (to kill the competition) and plant growth stimulants to increase root growth. In turn, some of those species will be food for still other species. Other organisms are free-living, adding to the richness of the soil ecosystem. Many of the species found in the soil ecology help the vascular plants, directly or indirectly—by creating or liberating nutrients, discouraging harmful organisms, or just by occupying a niche (a robust ecosystem has great diversity, which discourages both invasion and erratic population swings by the various species). Soil ecosystems are slow to reveal their secrets. Many of the "rotational effects" we observe are likely caused by shifts in the soil community, as they are not explainable by moisture levels, nutrient cycling, or known diseases.

Photo by Andrew Reuschel

Annual ryegrass roots seeks nutrients by growing into and all around the void left by a decomposed radish. Life begets life in the soil!

Underworld inhabitants also have many desirable effects on soil physical characteristics. Want to loosen and aerate the soil? Earthworms can handle that for you, as can plant roots. Redistribute nutrients? Earthworms again. Help plant roots absorb nutrients and water? Mycorrhizal fungi to the rescue. All of these helpers work best in continuous no-till.

Building a Better System

All of this is just leveraging biology in our favor and the secret is in figuring out how to let nature solve your problems for you. Fields are ecosystems, and they may either be on life-support or be quite robust. The take-home message is that, in the biological world, brute force generally fails and technology is usually expensive. Biological solutions often can be "persuaded" to work for less cost, and they are "on the job" when and where they are needed—much more so than applied inputs. None of this is intended to be an "avoid technology" message—technology is wonderful, however, it seems that we have gotten sloppy in thinking technology will bail us out of every jam. Your fields will always be a messy tangle of wild biology. Embrace it and learn to leverage it.

Around soil health and conservation, the questions we ask have been mostly about practices, species, or substances. Practices such as terracing, buffer strips, strip till; species for CRP seeding or edges; and substances such as plant-available nitrogen, phosphorus, or organic matter. These questions are important, and they help guide practical action, but there is another less immediately visible dimension. This is the flows and changes of sunlight energy that drive water and carbon cycling, which together make up the most powerful planetary force. Our agriculture and land management have changed and continue to change these flows of sunlight energy in ways we may not intend or be aware of.

Since the 1880s, our government has spent hundreds of billions on controlling the rivers in the Mississippi-Missouri system. Since 1931 our nation has spent hundreds of billions on soil conservation. Have we been dealing with a symptom or a cause? According to a U.S. Geological Survey report on the Mississippi-Missouri basin, precipitation increased 2.1% per decade from 1949-1997 in the basin, while estimated total runoff increased 5.5%, some of this not making it to the Gulf because it was held behind dams. The unavoidable conclusion is that the soils of the central U.S. have become increasingly compacted and less able to infiltrate or store water. Basin-wide, we do a poorer job of capturing rain where it falls, missing our biggest opportunity to capture sunlight energy as water held in covered, porous, well-aggregated soil. This amounts to a massive sunshine spill and observers point to the flooding of 2018-19 as a bigger ecological disaster than the BP oil spill.

Most of us now realize that maximum sunlight capture depends on green plants with living roots feeding the soil foodweb through photosynthesis, driving the biological carbon cycle that feeds us all. If we're going to take responsibility for the capture of sunlight energy, it helps to be able to see it over time. Satellite data can be an asset here. People use satellite data to look at a vegetative index to show crop stress or predict yields, but we can also ask some different questions about energy flow on our croplands, as with these maps:

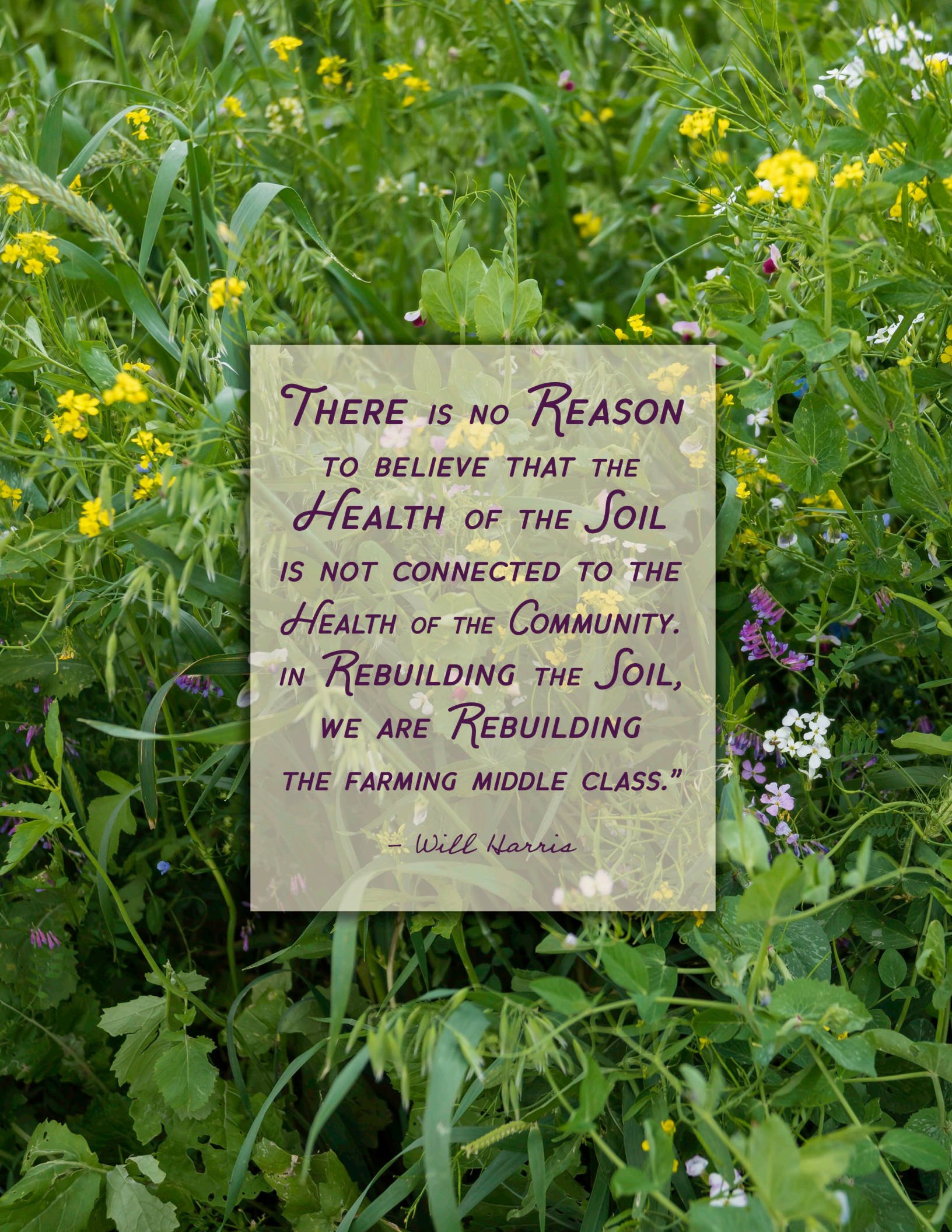
This first map (see previous column) shows, in darkness of green, the intensity of photosynthesis (NDVI) from July 25 to August 15 in 2018 for an area just north of Elkhart, Illinois. The red marker on the left is in a field where cover-crop experiments are being tried. The marker on the right is business as usual for the corn belt: short-season annual cropping of corn or beans.

The above map shows duration of photosynthesis rather than momentary intensity and is nearly the reverse of the summer map. Same area, same markers, this map shows number of days in which photosynthesis was over a threshold (in this case, NDVI over .3) The darker the green, the longer soil life is being fed by plant photosynthesis such as root exudates, and the more chance soil life has to grow and maintain soil structure and aggregation. The marker on the left shows a huge increase in the capture of sunlight energy, with cover crops providing a much longer season of plant growth.

Maps of energy flow can give us additional perspective and underscore the need for the implementation of soil health principles of soil cover, living roots, diversity, minimize tillage, and integrate livestock.

By Peter Donovan

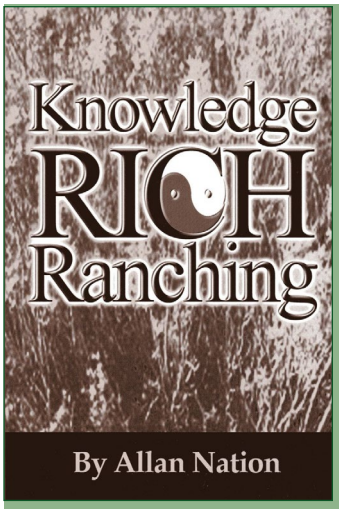
Peter Donovan founded the Soil Carbon Coalition in 2007 and shortly afterwards embarked on the Soil Carbon Challenge: soilcarboncoalition.org/challenge. For many years, Peter has written on innovative natural resource stewards, and most of his articles can be found on ManagingWholes.com.



There is no Reason to believe that the Health of the Soil is not connected to the Health of the Community. In Rebuilding the Soil, we are Rebuilding the farming middle class."

– Will Harris

There are hundreds of great resources in addition to this resource guide that are full of good information on soil health. We asked some of our sales representatives and regional partners to share some of the resources they have found to be the most helpful.



"Knowledge Rich Ranching" was one of the most valuable and influential books I have read regarding cattle production and grazing. In addition to an abundance of practical advice, author Allan Nation focuses heavily on how a rancher must think. This book keeps focus on how to make consistent profits with cattle, rather than getting caught in the ranching activities we think we need to do but don't make us any money. Reading this book made me feel like I was getting an unfair advantage over any producers who have not read this book. Be prepared to highlight and take notes!

Davis Behle

For the past fifteen years I have raised a small herd of Angus cattle with my dad. Although I currently live in town, I aspire to have a place in the country where I can run a cow calf or stocker herd on pasture and annual cover crops.

If you have Facebook and are interested in regenerative agriculture and cover crops, you have to join the "Everything Cover Crops" Facebook group. Every operation is unique, but with over 11,000 members, you are sure to find someone going through a similar situation that is willing to share their experience. Everyone is still learning and figuring things out, but if we can pool our resources together and learn from each others' mistakes, it makes it that much easier for newcomers to thrive. The willingness to share information with like-minded individuals is really what sets this group apart.

Noah Young

Throughout the last 8 years working here at Green Cover Seed I have developed a passion for regenerative agriculture and soil health. I am excited to begin my journey as a first generation producer using the knowledge I have gained from Green Cover Seed and others in the industry.

Greg Judy is one of the most influential producers on which I have built my young operation's foundation. Focusing on low input, regenerative livestock production, silvopastures, exploring income opportunities for expansion with limited inputs, and more. I have read both of his books, "No Risk Ranching" and "Comeback Farm". Greg created his YouTube channel, "Greg Judy Regenerative Rancher" to reach a growing audience base.

Colten Catterton

I am a Sales Representative for Green Cover Seed, and also am growing hair sheep in the fertile hills of NW Missouri. I am implementing Management Intensive Grazing (MIG) to achieve my passion of regenerating our natural resources. I view myself as a forage producer that utilizes sheep to turn biomass into a sustainable income.

My favorite resource is the website www.onpasture.com. On Pasture is updated weekly with practical, economical, and informative articles rooted in helping improve the soil. Usually, but not always, the articles are from producers who want to share their experience and knowledge to help others.

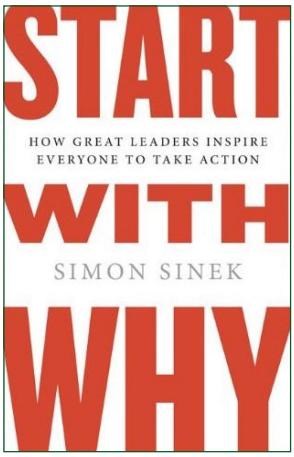
Kurt Dale – Dale Family Farms

At Dale Family Farms, we provide a source of quality, nutrient dense meats raised on our small, family farm. We have come to understand that the health of our animals and the healthfulness of the food we raise and eat is directly correlated to the quality and health of the soil on which it is grown.

One of my favorite resources on the topic of soil health is the Cover Crop Strategies podcast. Steve Groff does a great job covering a wide variety of topics in the episodes. It discusses all kinds of different situations and how cover crops come into the picture in those scenarios as he brings in his experiences from all over the country and the world. Each episode I listen to increases my knowledge of cover crops, which in turn gives me the opportunity to pass that knowledge along to others as well! I appreciate the very practical, no-nonsense approach that Steve Groff takes in putting these together.

Jakin Berns

I currently live in Jackson, MS working as a Sales Representative for Green Cover Seed. I look forward to opportunities ahead where I can further implement what I have learned about cover crops and soil health, and the impact these practices can have nationally and globally.



"Start with Why" by Simon Sinek. Choosing just one resource is very difficult. We use a plethora of soil health resources from books, to YouTube videos, to single page publications, all of which inch us a bit further in our understanding of how to adopt soil health practices and help others in their journeys. While there is always more to learn about soil health, the hardest part is the correct mindset. Not just at first, but you have to continually remind yourself throughout your process. If you can find your why, it continually guides and resets your course. It helps you in each of your decisions. It gives everything you do, even the mundane tasks, purpose. While this is not a "soil health" resource, the fastest way to regenerate your soil is you.

Kate Vogel – North 40 Ag

At North 40 Ag, WHY is the center of all that we do, from mixing seed, working with customers, to team meetings. We seek to provide a community to improve lives and regenerate agriculture. This helps us to make soil health practical to each of us as individuals, which allows us to be better resources to other producers.

Dr. Allen Williams and Joel Salatin are two of my favorite resources for implementing practices into my operation. They both focus on diversifying the farm, whether it's plants, animals, or both, and intensity of rotation for not only building soil health, but for human health. Dr. Allen Williams is the Chief Ranching Officer at Joyce Farms and you can find many of his articles on their website along with great YouTube videos of his talks. (joyce-farms.com). Joel Salatin has written many books and has a wonderful YouTube presence on 'how to' management for implementing new species into the farm. I have read his books "Folks, This Ain't Normal" and "You Can Farm". Salatin does a fantastic job of inspiring you to start farming or change how you farm.

Brett Peshek

I'm currently using an AMP (Adaptive Multi-Paddock) grazing system to regenerate a 240 acre farm in Mountain View, OK with a cow-calf operation. I use AMP, along with mixed species covers to reduce input costs, improve soils, and diversify perennial pastures.

My favorite resource for keeping up to date with soil health is Twitter. I like being able to see in real time what some of the innovators (Loran Steinlage, Josh Lloyd, Jason Mauck, Grant Sims, Tom Robinson, Michael Thompson, John Heermann, and others) in Agriculture are doing. I find it interesting to be able to go around the world in a few minutes and see different crops and ways of growing them that I know nothing about. I also follow many farmers and ranchers that I have nothing in common with, as far as production practices go, just so I can try to understand why people do what they do.

Scott Ravenkamp

I was a farmer/rancher in Eastern Colorado for 25 years before deciding a change of pace in life was necessary and moved to Verdigre, NE where I am a Contract Production Manager for Green Cover Seed and hobby farmer/rancher..

Grass Fed Solutions offers tons of information on beef production using a grazing approach to all systems. This is where it started for my operation, as one of the first videos I ever watched was Soil Carbon Cowboys featuring Dr. Allen Williams, Gabe Brown, and Niel Dennis. That video is packed with useful information that will help you understand what the actual goal is of raising livestock. The website offers fencing advice as well as the most asked question of "how do we water?".

Zach Louk

I have a beef cow/calf herd as well as some crop ground that has been primarily soybeans/corn in the past. We are now using that ground to increase our grazing, and reduce our hay feeding in the winter. Thanks to Grass Fed Solutions, I utilize rotational grazing with my cattle in all types of pasture systems every month of the year.

The resource I would recommend is the Soils and Men 1938 Yearbook of Agriculture. This classic book is one of my most treasured possessions. It is obviously out of print, but is found in many libraries. It contains a lot of knowledge and information about farming in the days before synthetic nitrogen fertilizer and pesticides were readily available, a time in which principles like crop rotation and cover crops and manure management were essential to success. Even though it is now 80 years old, it is amazing how the chapters on the value of soil organic matter and the destructive nature of tillage sound as if they could be something a speaker at a present day soil health meeting would be saying.

Dale Strickler

SMARTMIX®

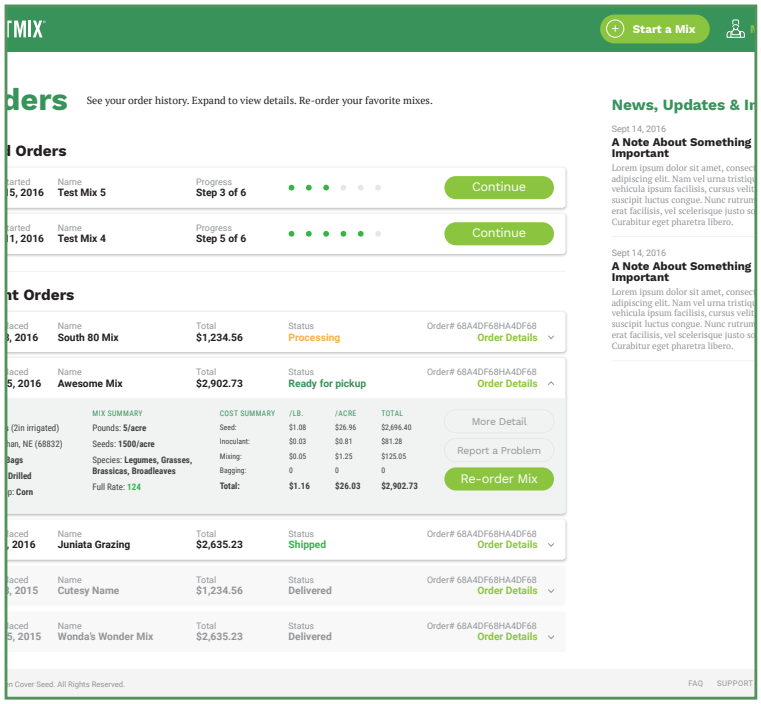
SmartMix® Calculator

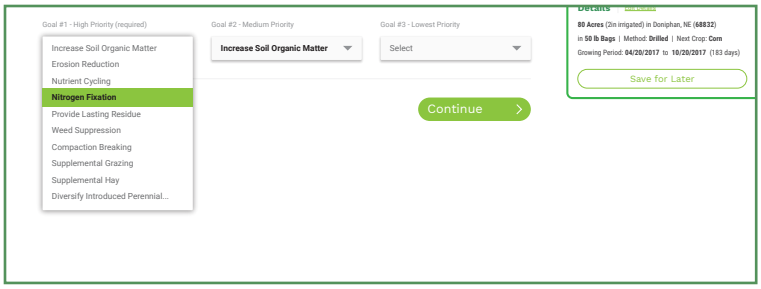
The best cover crop decision making tool in the industry, SmartMix® Calculator 5.0, is more robust and richer in features than any other decision making tool available online. Featuring a simplified user interface, clean graphics, and the ability to edit previous mixes, SmartMix® 5.0 is setting the standard for cover crop design tools!

SmartMix® is free for everyone to use, but you will need to create an account (if you do not already have one). This allows each user to have a record of saved and submitted mixtures and allows recall, review, or editing of previously created mixtures. All information contained within your account is kept confidential and will not be shared with anyone outside of Green Cover Seed.

Mix Details

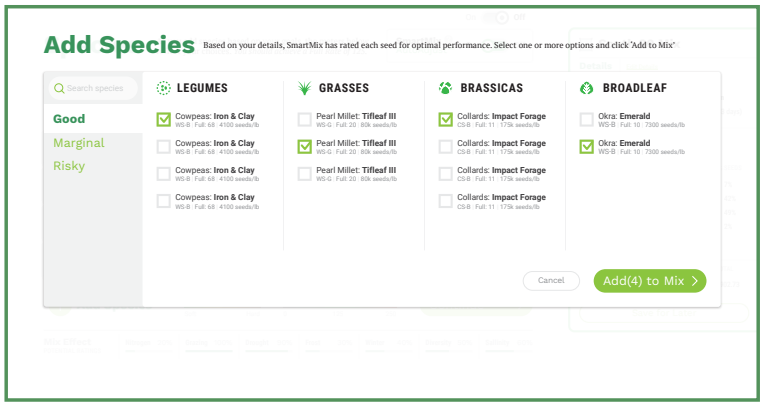
SmartMix® 5.0 is very interactive and allows the user to input details such as zip code, mix name, seeding method, next cash crop, acres, seeding date, termination date, and up to three goals for the mix. SmartMix® will also factor in average annual precipitation, first and last freeze dates, growing degree days, projected irrigation, and plant hardiness zone of any selected zip code.





Species Selection

SmartMix® 5.0 is loaded with more than three million data points including growing degree days, precipitation data, and frost data for all 45,000+ continental state zip codes as well as data on over 100 cover crop species. SmartMix® 5.0 gives ratings for species suitability based on user-inputted goals, planting dates, and geographic location. Mix ratings for C:N ratio, nitrogen fixation, grazing suitability, frost tolerance, winter hardiness, salinity tolerance, and diversity ratings are also calculated. Based on all of the geographical, climatic, and agronomic data gathered during the previous step, SmartMix® will help the user choose the best cover crop species for their unique situation. Species within each family will be ranked by suitability based on goals, location, planting time-frame, and next cash crop. These rankings are based on general plant properties and must still be carefully considered by the user, but it gives some guidelines and starting points for the user.



After a species has been selected, a suggested full seeding rate will be given. The user must then decide how much of each species to put in their mix. To keep the mix balanced, we suggest keeping the "Full Rate %" of the overall mix at around 125% for most mixes, with grazing and highly diverse mixes going up to 150-175%.

As a mix is built, ratings for nitrogen fixation, grazing, drought tolerance, frost tolerance, winter hardiness, diversity, and salinity tolerance are given. The Carbon:Nitrogen ratio is also estimated for the mix as it is being

designed. A complete accounting of the cost of the mix is calculated and shown in real time. The total is broken down for seed cost, inoculant cost, mixing cost, and bagging cost. Additional information may need to be collected in order to accurately calculate shipping, and we will contact you with a shipping quote after the mix has been submitted.

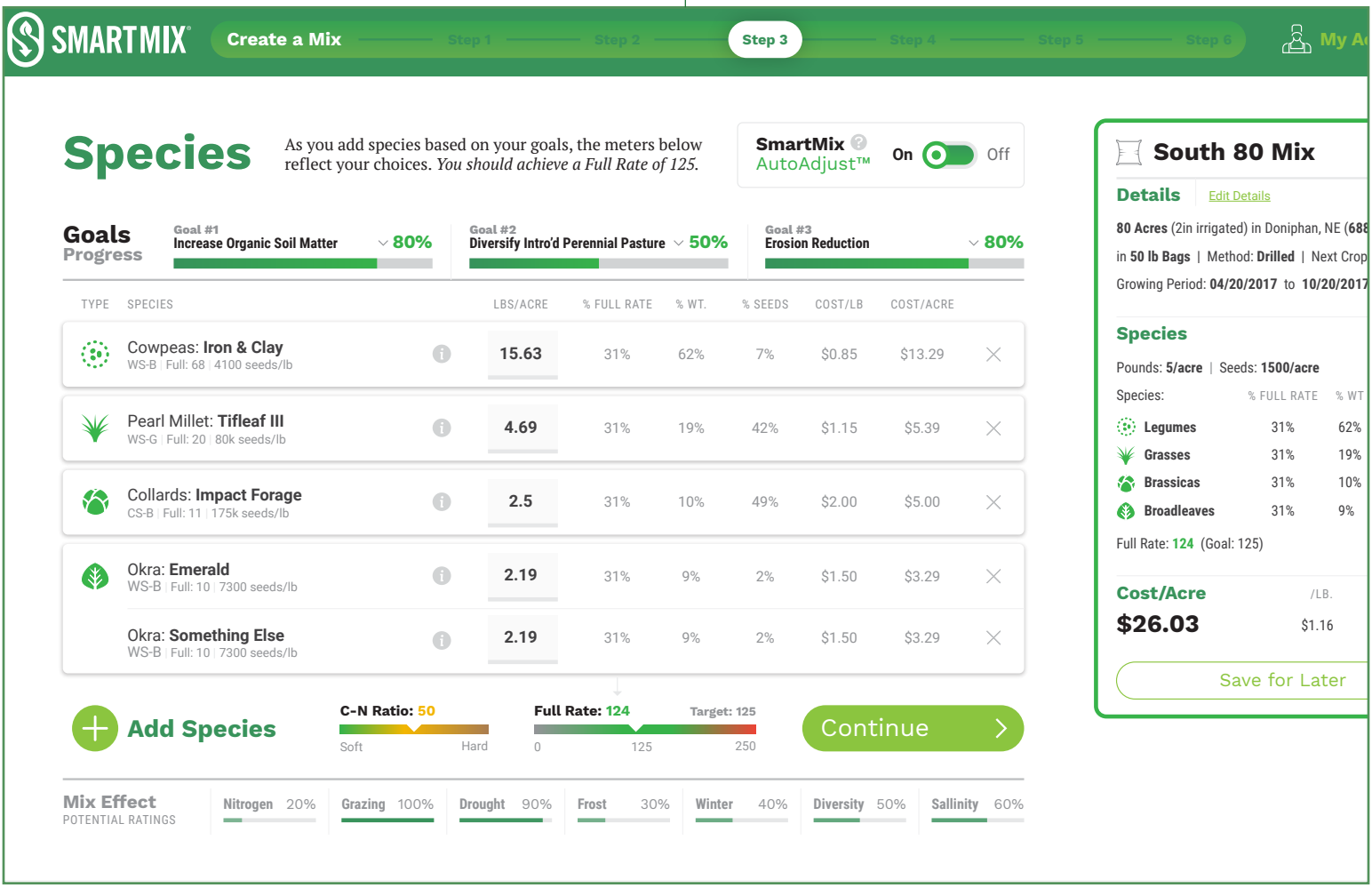
Feel free to experiment with different species and observe how each selection and seeding rate change affects the calculations, ratings, and cost of the mix. We have found this feature to be highly addictive, and many hours can be spent running through "what if" scenarios and comparing one mix to another!

SmartMix® is designed as an educational tool to help the user make decisions about what cover species to choose. Some of the species suggestions may not be familiar to the user, therefore, more information about each cover crop species can be obtained by clicking on the information icon, which will access detailed information pages about cover crop species from the Green Cover Seed website. SmartMix® 5.0 is designed using the latest technology, and best results will occur when using the latest release of the browser of your choice. Older versions of Internet Explorer are not able to run the new code, so please be sure you have the latest version.

We have a three-part tutorial on how to use and utilize SmartMix® 5.0. Go to YouTube and search for the Green Cover Seed channel or search for SmartMix Tutorial. To ensure you will get notified about new videos, please subscribe to our YouTube channel.

"Thank you for the personal note this morning! Kudos to your developers for the SmartMix calculator. I am at the beginning of my farming career and it was really informative and helpful to put together a mix that meets the goals for my land. I worked with Carli and Adrienne to get my order placed - they were awesome to work with and I look forward to working with your team more in the future as I grow my operation."

Jake H, Wisconsin



It has been observed that a mixture of plants often performs better than a monoculture of the best performing plant in the mix. Each plant species has unique liquid carbon root exudates which feed a diverse community of microbes, which in turn makes the whole system work. This is one of the reasons we try to create diverse cover crop mixtures instead of just picking the highest yielding or the "best ones". Plant diversity also provides different root types for better use of soil resources, a layered canopy for better capture of sunlight, better livestock nutrition for grazing, and far lower risk of any one insect or disease taking out the stand. Green Cover Seed is the leader in designing and delivering customized diverse cover crop mixes. We encourage you to use the SmartMix® Calculator (see pages 56-57) to experiment with designing mixes, or call or email us and we will help design the best mix for you. Here are some basics of cover crop mixology.

Spring Planted Mixes

Spring plantings are commonly utilized to jumpstart soil biology after a long cold winter. These cover crop mixes are used to "prime" the soil biology ahead of a later spring planted crop. Spring mixes are also used in the western Great Plains as a "fallow replacement", where a living cover provides extra residue and biological diversity for the soil. Moisture used by the cover crop is usually gained back later in the summer through increased infiltration and decreased evaporation. These mixes can be seeded when soil temperatures maintain 40°F; however, greater diversity can be added to these mixtures if planting date is delayed until closer to the frost-free date.

Photo by Brett Peshek

Late Spring/Early Summer Mixes

Late spring and early summer plantings are commonly utilized as a forage source for livestock when summer heat begins to reduce cool season grass forage production. These mixes can also be used on prevented planting acres to add biological diversity, suppress weeds, produce nitrogen, and cycle nutrients during the prevented plant year. These mixtures consist of both cool season and warm season species so soil temperatures need to reach and maintain 55-60°F and the last frost risk has passed.

Midsummer Mixes

Planting covers after a summer-harvested cereal or pea crop is the perfect opportunity to implement very diverse cover crop mixes into a cropping system. Converting the ample hours of summer sunlight into forages and soil nutrients is one of the best ways to improve the biological health of your soil. With so many cover crop options to choose from, these mixes will be driven by your specific goals. These mixes can also work well for early silage fields and seed corn fields. Warm season species will dominate these mixes with a few strategic cool season species added for diversity.

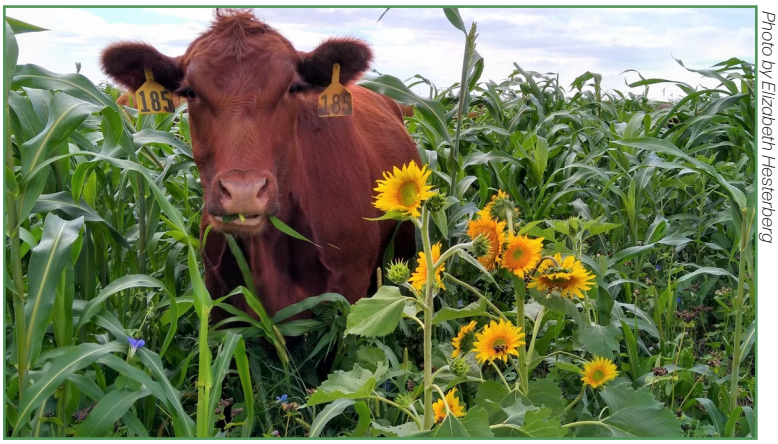


Photo by Elizabeth Hesterberg

Late Summer Mixes

In the late summer there is a terrific window of opportunity for both warm and cool season species to be used together. Warm season species will decline after the first killing frost, leaving the cool season species to continue to thrive and be productive.

Fall Mixes

Cover crops seeded into or after fall-harvested crops can be beneficial for the soil, but can present challenges for seeding the covers. Fall mixtures vary greatly depending on your goals, planting method, and timing. Here are some basic guidelines to follow:

Planting 4-5 weeks prior to first frost: Use any cool season or fast-growing warm season species for significant amounts of biomass production prior to frost. In many areas, this may require broadcast seeding prior to fall harvest.

Planting 2-3 weeks prior to first frost: Cool season species that winter-kill at temperatures below 25°F or overwintering species are good choices. This is also the ideal time to plant overwintering crops for forage or seed production for the following year.

Planting at or after first frost: With limited heat units remaining in the season, only invest in species with overwintering potential. Fall growth will be limited, so use winter hardy cereal grasses, and winter hardy legumes can be added if there is adequate time for spring growth prior to the next planted crop. Timing of termination in the spring is an important management decision that will have to be made.

Stock Cover Crop Mixes

While we specialize in making diverse custom blends specifically for each customer's needs, there are some situations where we offer predesigned mixes that will be more cost efficient for the customer who does not have large areas to seed.

Wildlife Mixes

- Cool Season Deer Mix
- Warm Season Deer Mix
- Upland Game Mix

We offer three diverse wildlife mixes that are dual purpose as they are designed to feed the biology in the soil as well as the wildlife above ground! Our Warm Season Deer Mix provides a consistent food source during the heat of the summer and into the fall, while our Cool Season Deer Mix is designed to attract deer in both the early and late hunting seasons. The Upland Game Mix is a perfect fit to attract dove, quail, pheasants, and turkey by providing both habitat and nutrition. Perfectly designed to attract insects for chicks while providing the kind of protection that will keep the birds from ever needing to leave your property.

Soil Building Mixes

- Cool Season Soil Builder Mix
- Warm Season Soil Builder Mix
- Mycorrhizal Mix
- High Diversity Mix

At Green Cover Seed, we really mean it when we say "High Diversity". Our High Diversity Mix has almost 20 different species!

Each of these Soil Building Mixes do a tremendous job of improving the soil. With a vast array of root depths and structures as well as excellent above ground growth, these mixes are built to help increase your soil organic matter. Because of the growth potential and diversity offered in these mixes, they are also an excellent option for weed control.

Pollinator Mixes

- Cool Season Pollinator Mix
- Warm Season Pollinator Mix
- Perennial Pollinator Mix

We offer three different pollinator mixes to fit your needs all through the year.

For every yield-robbing pest, there are 1,700 other insects that are beneficial. Why spend money on chemicals to target just a few bugs when you can let Mother Nature take care of herself by importing thousands of beneficials. These diverse mixes each have over 20 flowering plants and are designed to attract those insects and serve as an excellent food source. The variety of different colors in flowers will attract many different insects benefiting both the plant and soil. If you want to promote life in your field by importing thousands of new, beneficial inhabitants, this mix is for you!

Photo by Mac Kincaid

Visit www.greencoverseed.com to learn more about these mixes including the specific ingredients of each mix. You can also place an order straight from our website!

Legumes are critical components of any cover crop mix. They possess the unique ability to form symbiotic relationships with rhizobia bacteria that fix atmospheric nitrogen inside nodulation colonies that grow on roots. A pure stand of legumes can fix 120-180 pounds of N per acre, and in a mix legumes can fix 30-80 pounds of N per acre. Legumes are high in protein, generally very palatable for livestock, and have a low carbon to nitrogen ratio. Because legumes typically yield less seed than other plants, legume seed is generally more expensive.

Sunn Hemp

Sunn hemp's vigorous growth rate and nitrogen fixing capabilities make it an attractive cover crop to build residue, sequester nitrogen, suppress weeds, and improve soil health. When planted as a summer annual, sunn hemp grows rapidly and can get 6-7 feet tall, produce 3-5 tons of biomass, and produce 120-140 pounds of nitrogen per acre in 60 days. Sunn hemp is a tropical plant and requires warm soil temperatures for germination and 45-60 hot days are needed to accumulate growth before the first frost. Sunn hemp has also been found to greatly reduce soybean cyst nematode populations.

Mung Beans

Mung beans are the shorter season and more determinate cousin to cowpeas. Equally drought and heat tolerant, but with smaller seed size, mungs are a great warm season legume planted later in the season (after wheat harvest) when the growing season is limited. Mostly upright and slightly spreading, this low water use plant is a good addition to grazing mixes with crude protein ranging from 16-22%.

Hairy Vetch

Hairy vetch is the most widely planted winter legume, because it is the most winter hardy of all legumes. Depending on genetics, properly established hairy vetch can survive subzero temperatures and with some snow cover it can survive double digit subzero temps. For this reason, hairy vetch is widely used by organic producers who need to fall plant a legume for spring nitrogen production ahead of organic corn production. Nitrogen production from hairy vetch can range from 80-200 pounds per acre and is highly dependent on allowing the vetch to maximize its growth into the spring. Early termination can lead to reduced N fixation rates. Hairy vetch has a great rooting system, with a tap root that will extend up to 3 feet into the soil profile with many fine branch roots going horizontally through the soil. This rooting system will allow the vetch to thrive even in dry conditions. There is a weed risk associated with hairy vetch because a percentage (0-10% depending on genetics) of seeds will have a hard seed coat which can lay dormant in the soil for several years. This is generally not a problem in a corn/bean rotation, but is more of a concern for producers with cereal grains in their rotation.

4010 Spring Peas

4010 Spring Peas are one of the most widely planted spring legumes. Their rapid spring growth can be very effective at suppressing weeds and they can produce 90-150 lbs of nitrogen per acre with enough growing time. The pea residue breaks down rapidly, releasing the N quickly. Once established they can withstand heavy frosts. Since peas have no hard seed and because they can easily be killed by herbicide at all growth stages or crimping at flowering, they will not become a "weed". Peas produce excellent forage for grazing or haying and have high water use efficiency. For maximum forage yield, peas should be mixed with a grass like oats or barley to support plant growth. Peas can slightly increase forage yield but will really boost forage quality, especially the protein levels.

Balansa FIXatioN Clover

FIXatioN balansa clover is the most cold-tolerant annual clover; it can withstand temperatures down to -14˚F. FIXatioN can tolerate a variety of soil types and can even grow through short periods of standing water. As an annual clover, FIXatioN also helps with soil drainage and water infiltration due to its deep tap root system. Due to the very small seed size, balansa requires less pounds of seed per acre than many other clovers. Flowering will occur about two weeks later than crimson clover in the spring and can last for about 4-5 weeks. The flowers can range from white to pink and are very attractive to pollinator insects. As balansa matures it produces very large hollow stems, making a roller/crimper a viable termination method. FIX your soil today with FIXatioN balansa clover.

LEGUMES

Warm Season Legumes	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Cowpeas (Red Ripper)	4,100	32	Excellent	Excellent	Excellent	Poor	More viney type cowpea
Cowpeas (Iron and Clay)	4,100	32	Excellent	Excellent	Excellent	Poor	Longer maturity cowpea
Mung Beans	7,000	32	Excellent	Good	Excellent	Poor	More determinate than cowpeas
Guar	12,000	32	Excellent	Good	Excellent	Good	Beans stay in pods for winter stockpile grazing
Sunn Hemp	15,000	32	Good	Excellent	Fair	Fair	Fast growing
Soybeans	3,300	32	Good	Good	Excellent	Poor	Long maturity and non GMO
Korean Lespedeza	200,000	32	Good	Fair	Good	Fair	Good for pasture interseed

Cool Season Legumes	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Spring Lentils (Indian Head)	21,000	20	Excellent	Fair	Good	Poor	Small seeded pulse
Winter Lentils (Morton)	21,000	0	Excellent	Fair	Good	Poor	Decent over wintering
Common Vetch	8,000	10	Good	Good	Good	Poor	Lowest cost vetch
Woolly Pod Vetch	10,000	0	Excellent	Excellent	Excellent	Poor	Fastest spring bloomer
Hairy Vetch	12,000	-20	Good	Excellent	Good	Poor	Best over wintering legume
Spring Forage Peas (4010)	3,200	20	Good	Excellent	Excellent	Poor	More forage than yellow peas
Winter Peas (Austrian)	4,000	5	Good	Excellent	Excellent	Poor	Small seeded peas
Chickling Vetch	2,500	15	Good	Good	Good	Poor	Great N fixer, larger seed
Faba Beans	2,000	15	Good	Good	Good	Poor	Can tolerate cool, wet soils. Large seed
Chick Peas	3,000	20	Good	Good	Good	Fair	More heat tolerant than other cool seasons
Crimson Clover	120,000	5	Good	Good	Excellent	Poor	Fast growing clover
Berseem Clover (Balady)	150,000	20	Good	Fair	Excellent	Poor	Mediterranean type
Berseem Clover (Frosty)	150,000	10	Good	Good	Excellent	Poor	Good cold tolerance for berseem
Balansa Clover (FIXatioN)	500,000	-5	Good	Good	Excellent	Poor	Good winter hardiness
Arrowleaf Clover	270,000	15	Excellent	Fair	Excellent	Good	Drought tolerant
Persian Clover	150,000	20	Fair	Fair	Excellent	Poor	Mediterranean type
Hubam White Sweet Clover	240,000	25	Excellent	Excellent	Good	Excellent	Best summer clover
Yellow Sweet Clover	180,000	-10	Excellent	Excellent	Good	Excellent	Biannual - deep-rooted, saline soils
Subterranean Clover	150,000	20	Fair	Poor	Excellent	Poor	Most shade tolerant
Ladino White Clover - perennial	500,000	-15	Good	Fair	Excellent	Fair	Long-lived perennial
Red Clover - perennial	190,000	-10	Excellent	Excellent	Excellent	Poor	Short-lived perennial
Alsike Clover - perennial	450,000	-10	Good	Fair	Excellent	Good	Tolerant of wet soils
Sainfoin - perennial	18,500	-15	Excellent	Good	Excellent	Good	Drought tolerant
Alfalfa - perennial	150,000	-15	Good	Excellent	Excellent	Fair	Very productive legume

Chart Key: Poor | Fair | Good | Excellent

Grasses are the workhorse family of the cover crop world, generally producing the highest yields and greatest biomass. Grasses comprise the bulk of many mixes, including most grazing mixes, and are generally very palatable for livestock. Grass plants tend to be higher in carbon to nitrogen ratio and can provide excellent residue if allowed to go to maturity.

Sorghums

There is no more versatile and widely used family of cover crop species then sorghum and its array of relatives. There are many purposes for which sorghum plants are suited, and different types and traits have been developed to meet these needs.

Sorghum Types

Sudangrass is a fine-stemmed sorghum that regrows rapidly after defoliation. It is earlier maturing and lower yielding than other sorghum types if all are allowed to grow to full maturity. It has a lower sugar content than other sorghums, but is higher in protein and palatability. Sudangrass is lower in prussic acid potential than other sorghum types.

Forage Sorghums are coarse-stemmed, long maturity sorghums that are higher in sugar and historically used as a source of syrup. Today they are used as breeding stock for many modern hybrids to enhance sugar, growth, and palatability. They have poor regrowth but high yield potential if allowed to grow to maturity.

Sorghum-sudans are hybrids between sudangrass and forage sorghum. They are intermediate in most characteristics but also exhibit hybrid vigor, and thus have excellent yield and regrowth potential.

Sorghum Traits

Brown Midrib (BMR) is a naturally occurring mutation that makes plants less able to produce indigestible lignin, which give them higher digestibility and far better (usually about 30% better) animal performance than non-brown midrib varieties of similar genetics. If a sorghum is to be used for animal feed, a BMR is preferable.

Brachytic Dwarf (BD) is a trait that shortens the internodes on a plant, but actually increases the total number of leaves on a plant. This results in a leafy, short-statured plant with low-set growing points that tends to stand better later in the season.

Dry-stalk (DS) is a trait in which the pith of the plant has less water content than most hybrids, meaning it can dry out faster in a swath than other hybrids of similar stem diameter.

Photoperiod Sensitivity (PPS) prevents the sorghum plant from heading out until the day length drops below 12 hours and 20 minutes, which for most areas will be mid-September. Heading is undesirable in a plant used for forage, unless the plant is intended for silage. Four things happen when a plant heads out and they are all bad for forage production: first, leaf production stops; second, root growth stops; third, the amount of lignin goes up and the plant becomes less digestible; and fourth, water use goes up from 30% to 50%. By delaying heading, a PPS hybrid will be very high-yielding, retain forage quality for longer periods of time, and be very water efficient.

Delayed Maturity (DM) is similar to photoperiod sensitivity but does not depend on day length to function, but rather a large amount of heat units.

Male Sterile (MS) hybrids have pollen that is not fertile, and thus cannot self-pollinate, and will not produce seed unless pollinated by another sorghum. MS hybrids are a great choice to prevent any chance of volunteer seedlings the next year but need to be isolated from other sorghums (including Johnsongrass) for a quarter mile to prevent seed production.

Best Sorghum Traits for the Situation

Summer Grazing: Rapid regrowth and low-set growing points (for grazing tolerance), as well as a very high leaf-to-stem ratio, and high digestibility. Look for a BMR, BD sorghum-sudan.

Hay in Humid Areas: Multiple cuttings, high digestibility, rapid regrowth, and rapid drydown. Look for a BMR, DS sorghum-sudan.

Hay in More Arid Areas: Single large cutting, delay heading as long as possible. Look for BMR, PPS sorghum-sudan or DM sorghum-sudan for later plantings.

Stockpiled Winter Pasture: Excellent standability, high digestibility, and palatability even when mature. Look for BMR, PPS forage sorghums or BMR, PPS forage sorghum-sudans, and if planting late (after July 4th, roughly) then a long maturity BMR, BD forage sorghum is the best choice.

Silage: Use a long maturity BD, BMR forage sorghum for early silage plantings. For later plantings, consider a shorter maturity BMR forage sorghum.

Biomass Production and Cover: Conventional sorghums and sorghum-sudans are the least expensive, but oftentimes a PPS, MS, or DM product may be desired to extend the growing season and prevent seed formation.

Wildlife Cover and Habitat: Use a blend of grain-producing hybrids with different maturities, lodging resistance, and heights. Consider adding a variety of millets as well.

Millets

Millets are diverse and broadly adapted group of summer annual grasses that fit a variety of needs. Because millets originate from Asia and Africa, they tend to have excellent heat and drought tolerance and in these countries of origin, they are still widely used as a staple for human consumption. There are a variety of different millets that serve a variety of different purposes, so it is important to understand the different types of millets and when and where they should be used, so you can select the one that is right for you.

Pearl Millet has the highest yield potential among millets because of its hybrid heterosis. Because millets have no prussic acid potential, hybrid pearl millet is preferred for grazing under conditions in which prussic acid might be hazardous. Millets, like any plant, can still accumulate nitrates and should be tested if high nitrates are a potential concern. Pearl millet is more tolerant of sandy and calcareous soils than sorghum-sudan, but less tolerant of heavy clay or wet soils. Pearl millet is usually higher in protein than sorghum, but loses palatability more rapidly upon maturity and unlike sorghums, pearl millet is safe for horses.

Foxtail Millet is also known as German or White Wonder millet. It is earlier in maturity and has lower forage yield potential than pearl millet; however, it is finer-stemmed and cures more rapidly for hay than pearl millet. When growing as a forage, be aware that once it heads out, it loses forage quality, and the bristly awns on the seedheads can cause sores in animal mouths. Foxtail millet should not be used for horses, as it contains a compound that can cause joint pain and problems with the urinary tract.

Browntop Millet is another rapid-maturing, lower-yielding (as compared to hybrid pearl) millet variety, commonly used in the southern plains as it is more tolerant to higher humidity levels but it can move north also. Browntop holds its palatability after maturity better than other millets so it has a fit in stockpile mixes. Browntop is also safe to feed to horses. It is often used in wildlife food plots as it is a good seed producer with an open panicle for easier foraging.

Japanese Millet matures rapidly and typically yields less forage than other millets but is more palatable than foxtail millet after maturity and has better regrowth. Japanese millet is exceptionally tolerant of wet soil and will even grow in standing water, finding use in duck food plots.

Proso Millet is used strictly as a grain crop and has very little forage value, being both unproductive and unpalatable. However, it is one of the most water-efficient grain crops, and is used to provide animal feed in areas too dry for corn or sorghum. It is also used as a rapid-maturing (as little as 60 days to maturity) grain crop when the growing season is too short for a full-season crop, such as when hail takes out the primary crop or for wildlife food plots.

Left: German Millet | Right: Pearl Millet - 5 weeks of growth

Teff Grass

Teff grass is a summer annual forage for livestock and commercial hay producers who need a fast growing, high yielding crop with excellent forage quality. Teff is fine stemmed, leafy and "soft" which makes it very palatable to livestock, especially horses. Teff is planted in late spring after the danger of frost has passed and can be harvested multiple times during the hot summer months. Teff germinates quickly and is usually ready for first harvest at the early boot stage 45-55 days after planting. Subsequent cuttings are usually ready for harvest in 28-35 days, depending upon growing conditions and the region. For more information about Teff grass, visit teffgrass.com.

Rye vs. Ryegrass

Many people, understandably, are confused by the difference between rye and ryegrass. These two plants, despite the similarity in names, are not closely related and do not behave alike.

Rye *(Secale cereal)* is a cereal grain, closely related to wheat, with which it can be crossed to form triticale. It is tall, has a course stem with a long seed head and contains grains that are approximately 25% smaller than wheat. Rye is the most cold-tolerant grain crop known, and will produce more growth during winter than any other crop. It is the last forage crop to freeze down in fall and the first to green up in spring, but is also the first cereal grain to get stemmy and unpalatable in spring. Rye is very tolerant of drought and sandy or low-fertility soil, but responds well to fertility. It does not like very wet soil. One drawback of rye is that volunteer plants are hard to control in wheat fields if allowed to go to seed.

Ryegrasses *(Lolium multiflorum)*, on the other hand, are true "grassy" plants, closely related to fescue with which it can be crossed to form the hybrid called festulolium. The seeds are small and fluffy, and are very hard to distinguish from fescue seed. The leaves are erect, dark green, and very shiny due to a waxy layer on the leaf surface.

Ryegrasses perform best in clay soils with good moisture, and tolerate wetter soils than any of the cereal grains. They have fine leaves and do not get very tall compared to cereals. Annual ryegrasses form a dense root system that can hold up animals and vehicles much better than cereals in wet weather. Ryegrass greens up later in spring than rye, but is much more grazing tolerant and grows later into the summer than rye. It also keeps its palatability and nutritional value much later in the season than rye. Annual ryegrass is not closely related to wheat like rye and there are herbicides that can take volunteer ryegrass out of wheat. Ryegrass comes in annual, biannual, and perennial forms, and even hybrids of annual and perennial varieties (intermediate ryegrass).

So which is the better pasture or cover crop choice, rye or ryegrass? Each has enough advantages that the answer is both.

Elbon Cereal Rye

Elbon cereal rye was developed by the Noble Foundation in Oklahoma and has a wonderful combination of winter hardiness and fast growth. Elbon has a shorter dormancy period than northern cereal rye and will give more fall growth as well as earlier spring growth.

It is excellent as a forage in early spring and will provide some of the best weed suppression and erosion control well into the early months of summer as a mulch. Elbon can be planted late in the season into soils as cold as 34°F.

Cosaque Black Oats

Cosaque oats are a black-seeded winter oat with better nutritional value, digestibility, palatability, and tillering ability than traditional oats. Forage yields are very similar to cereal rye. Black oats have good winter hardiness and are commonly a winter annual in the south. Black oats can survive in very poor-quality soil and help build the soil back through its fantastic root system.

813 Triticale

Triticale is a cross between rye and wheat and has some characteristics of each parent. Compared to rye, triticale holds its feed value better into late spring. This makes it well suited for hay, silage, or stretching grazing well into June if you don't mind starting two or three weeks later. The disadvantage to triticale is that it tends to be a bit more susceptible to winter injury than rye, but is similar to wheat.

Our top performing triticale is SY813, which is awnletted (very short beards), has excellent fall vigor and growth, and is tolerant of both rust and wheat streak mosaic virus. It is very well adapted to the Southern and Central Great Plains region. This is the go-to winter forage to maximize forage production!

Warm Season Grasses	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
BMR Grazing Corn	2,500	32	Good	Good	Excellent	Poor	Great value for forage
Sorghum Sudan	18,000	32	Excellent	Excellent	Good	Fair	High tonnage
BMR Sorghum Sudan	18,000	32	Excellent	Excellent	Excellent	Fair	Low lignin
BMR Sorghum Sudan PPS	18,000	32	Excellent	Excellent	Excellent	Fair	Photoperiod sensitive
Sudangrass	22,000	32	Excellent	Excellent	Excellent	Poor	Fine stemmed
Forage Sorghum	18,000	32	Excellent	Excellent	Excellent	Fair	Great for silage
Egyptian Wheat	18,000	32	Excellent	Excellent	Fair	Fair	Super tall sorghum
Wildlife Grain Sorghum	17,000	32	Excellent	Good	Fair	Poor	Good for upland birds
Pearl Millet	80,000	32	Good	Good	Excellent	Poor	Highest production millet
Browntop Millet	180,000	32	Excellent	Good	Excellent	Poor	Great heat tolerance
Japanese Millet	120,000	32	Good	Good	Excellent	Good	Grows in wet soils
Proso Millet	120,000	32	Excellent	Fair	Fair	Poor	Grain millet for birds
German Millet	180,000	32	Excellent	Good	Excellent	Poor	Excellent hay millet
White Wonder Hay Millet	180,000	32	Excellent	Good	Excellent	Poor	Excellent hay millet
Teff Grass	1,300,000	32	Excellent	Fair	Excellent	Poor	Very fine stemmed

Cool Season Grasses	Seeds Per Pound	Cold Kill	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Spring Oats (Hayden)	15,000	20	Good	Excellent	Excellent	Poor	Very versatile
Black Oats (Cosaque)	22,000	10	Good	Excellent	Excellent	Poor	Great forage, long season
Winter Oats (Bob)	19,000	10	Good	Excellent	Excellent	Poor	Overwinters in the South
Spring Triticale (Surge)	16,000	5	Good	Excellent	Excellent	Poor	Awnletted, high spring production
Spring Forage Barley (Lavina)	13,000	20	Good	Good	Excellent	Excellent	Beardless and salt tolerant
Winter Barley (P919)	15,000	0	Good	Good	Excellent	Excellent	Beardless, decent winter hardy
Cereal Rye (Elbon)	22,000	-30	Excellent	Excellent	Good	Good	Best weed suppression
Cereal Rye (Yankee)	20,000	-30	Excellent	Excellent	Good	Good	Northern type with bigger, hollow stem
Winter Triticale (SY813)	16,000	-10	Good	Excellent	Excellent	Poor	Great spring forage
Winter Forage Wheat (Willow Creek)	13,000	-10	Good	Good	Excellent	Poor	Very long season for later graze
Soft Red Winter Wheat (Gore)	13,000	-10	Good	Good	Excellent	Poor	Beardless, good grazer
Italian Ryegrass	190,000	0	Excellent	Good	Excellent	Fair	Biannual - best for spring planting
Annual Ryegrass	190,000	0	Excellent	Good	Excellent	Fair	Very deep rooted

Chart Key: Poor | Fair | Good | Excellent

Brassicas are a family of cool season, deep-taprooted plants that have become integral parts of many cover crop mixes. They are especially favored for their compaction-breaking ability and palatability to livestock. Brassicas have very small seeds, are generally low in carbon to nitrogen ratio, and do not provide long lasting residue.

Mustard

Mustard produces significantly more glucosinolates than other brassicas, which biofumigates the soil during decomposition, proving to be toxic to many soil pathogens and pests, but are not recommended for grazing. Mustard can tolerate low fertility soils ranging from well drained to moderately well drained. We carry three premium mustards:

White Gold White Mustard *(Sinapis alba)* grows faster than any of the other mustards and this aggressive early growth makes it an ideal weed suppressant. Additionally, when White Gold decomposes it produces a thiocyanate ion that is a potent germination inhibitor. Will begin to bloom 4-5 weeks after emergence.

Kodiac Brown Oriental Mustard *(Brassica juncea)* is a fast growing and powerful biofumigant. When the glucosinolates are decomposed, a thiocyanate ion is produced that aids in the suppression of soilborne pathogens including sclerotina, fusarium, and verticillium. Will bloom 5-6 weeks after emergence.

Indi Gold Indian Mustard *(Brassica juncea)* has similar properties to Kodiac but has the added benefit of being imidazolinone tolerant and still non-GMO.

Impact™ Forage Collards

Impact™ Forage Collards are highly nutritious and digestible for livestock. They are slow to bolt and flower when spring planted, making them an ideal choice for late spring and early summer grazing. They have also exhibited excellent ability to regrow after grazing, even under drought conditions.

Impact™ Forage Collards are small seeded and are priced more affordably than many other premium hybrid brassicas, giving them excellent value as a flown on cover crop or as a part of a diverse grazing mix. Impact™ Forage Collards have a deep-growing taproot and will not form a tuber or a bulb, instead producing very large and nutritious leaves. Impact™ Forage Collards have demonstrated the ability to stay green into late December in Nebraska, even after temperatures dropped below 0° F for at least one night.

Smart Radish®

The Smart Radish® is a totally new radish that was bred specifically for the cover crop and soil health market. This is not a Daikon, vegetable, or oil seed radish but is a totally new plant from top to bottom. Bred by Mr. Adrian Russel with Plant Research New Zealand under contract to New Zealand's Norwest Seed and being marketed in the United States by Green Cover Seed, this exciting new radish has some great new features that we are excited about.

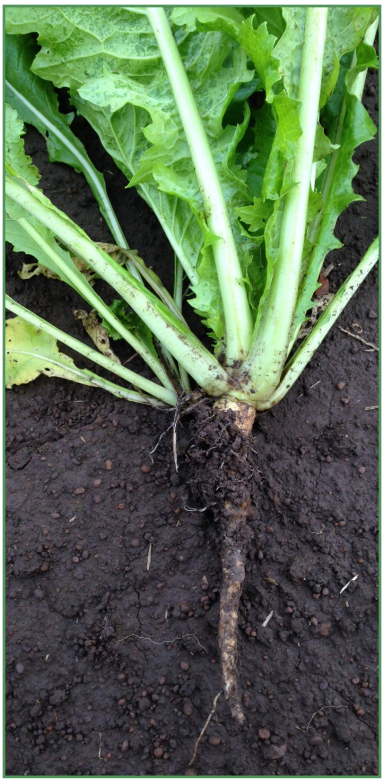

Photo by Alan Lill

- Smoother leaf for better forage and grazing.
- Higher plant biomass for forage, soil cover, and green manure.
- Higher plant tillering trait for more leaf area.
- Strong, penetrating "pull down" V-shaped bulb — more in the ground and less above the ground.
- Fibrous lateral rooting mass.


Photo by Alan Lill

"We used the collards in an area we had between our wall and our house where it is mostly shaded, and the soil is mostly all busted up concrete, rocks and sand. We mixed in what compost we had made, and attempted to rake out most of the larger stones, but it has very little "good soil". I was amazed again at how well the seeds sprouted and have taken off and grown. The rabbits feed on them once a week, but they keep on growing back."

Lee N – Haiti



Viva Hybrid Brassica

Viva Hybrid Brassica is a new, fast-growing, leafy brassica with little bulb development. It is best suited for multiple grazing. Viva bolts very late and has vigorous regrowth after grazing, while maintaining high feed quality and digestibility. With proper management, Viva has the potential to yield up to 10,000 lbs. of dry matter per acre over multiple grazing events. Viva can be planted with cereal grains or annual ryegrass in the spring or late summer to provide excellent tonnage and high quality forage.

Photo by Dale Strickler

Bayou Kale

Bayou Kale hybrid is a deep-rooted, medium-maturing forage brassica with good winter hardiness and excellent palatability. Bayou has a smaller stem and more leaf area than other brassicas. Bayou has excellent regrowth when rotationally grazed, and the stems are more palatable than forage rapes for cattle and sheep. Used in food plots for deer as well as upland game birds, animals will eat the Bayou first when planted beside rapeseed. When planted in late summer or early fall, it is considerably more winter hardy than radish and helps protect the soil longer from erosion. Initial observations show that when Bayou is grown for cover, it has the potential to reduce Soybean Sudden Death Syndrome and potentially reduces white mold.

Brassicas	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Daikon Radish (Nitro)	25,000	15	Good	Good	Good	Poor	Deep tap root
Smart Radish	25,000	15	Good	Good	Good	Poor	Pull down tap root
Forage Radish (Graza)	22,000	15	Good	Good	Excellent	Poor	Slow bolting
Oilseed Radish (Control)	22,000	15	Good	Good	Fair	Poor	Nematode suppression
Forage Collards (Impact)	175,000	5	Excellent	Good	Excellent	Poor	Great grazing forage
Purple Top Turnips	175,000	10	Good	Good	Excellent	Poor	Great value for grazing
Hybrid Turnip (Viva, Hunter)	175,000	15	Good	Good	Excellent	Poor	Excellent regrowth
Forage Rapeseed (Trophy)	175,000	5	Excellent	Good	Good	Good	Lowest cost brassica
Hybrid Rape/Kale (Bayou)	175,000	0	Good	Good	Excellent	Poor	Great winter grazer
Hybrid Turnip/Kale (Winfred)	175,000	0	Good	Good	Excellent	Poor	Great winter grazer
Kale (Siberian)	175,000	0	Good	Good	Excellent	Poor	Very cold tolerant
African Cabbage	180,000	15	Excellent	Excellent	Fair	Good	Stands well in winter
Camelina	180,000	-5	Good	Fair	Fair	Good	Most cold-hardy brassica plant
Broadleaf Mustard (Florida)	150,000	25	Good	Good	Fair	Fair	Huge leaves - best mustard for graze
Yellow Mustard (White Gold)	150,000	25	Good	Good	Poor	Fair	Best weed suppression mustard
Brown Mustard (Kodiak)	150,000	25	Good	Good	Poor	Fair	Nematode suppression
Oriental Mustard (Indi Gold)	150,000	25	Good	Good	Poor	Fair	Nematode suppression

Chart Key: Poor | Fair | Good | Excellent

Okra

Okra is a warm season broadleaf vegetable in the cotton family that is extremely deep-rooted and has excellent heat and drought tolerance. Okra's massive tap root is an excellent compaction breaker. This fast-growing plant provides a large canopy, long-lasting residue, and winter snow catch. Livestock will graze okra, as the pods are high in Vitamin A, C, and K, along with other minerals and vitamins that help strengthen the immune system and bones. Green Cover Seed is the nation's leader in cover crop okra.

Sugar Beet

Sugar beets are a broadleaf cover crop that can offer your operation another outstanding deep rooting crop with some frost tolerance. Sub-soiling thick taproots can fracture hardpans, and the majority of the root development is below the surface. Beets have a high sugar content and are preferentially grazed by wildlife and cattle. When grazed early enough, beets have shown outstanding regrowth.

Historically, sugar beet seed has been very expensive. We have contracted seed production with an Oregon farmer and are now offering non-GMO sugar beet seed at very competitive prices.

Flax

Flax is an annual, cool season broadleaf plant that can be utilized in many small-grain and corn rotations as a potential cover crop. Flax is a shorter plant that does not spread aggressively and has low input needs so it works well as a companion or interseeded crop, especially with sunflowers. Flax is high in lignin and is slow to decompose so it creates long-lasting, high-carbon residue. The pretty blue flowers of flax are a nice addition to any pollinator or insectary strips. Relatively small-seeded and inexpensive, flax is a good bargain and should be included in a great variety of cover crop mixes.

Safflower

Safflower is a drought tolerant, annual, warm season broadleaf that can be seeded in cool soils. Safflower has an exceptionally deep taproot that can reach depths of 8-10 feet, breaking hardpans, encouraging water and air movement into the soil profile, and scavenging nutrients from depths unavailable to most agronomic crops. Safflower provides excellent forage, but most varieties become very prickly with maturity, rendering the plants unpalatable for livestock. Baldy safflower is one of the world's first spineless safflower varieties and has been developed specifically for grazing and cover crops. Baldy can be handled with bare hands even at maturity and is palatable for livestock grazing. Green Cover Seed owns the exclusive marketing rights for Baldy spineless safflower.

Phacelia

Phacelia is a quick-establishing purple-flowering annual that is fantastic bee forage and is considered to be in the top 20 honey-producing flowers. Other beneficial insects and pollinators are also strongly attracted to phacelia. Phacelia is a long-day plant and should be planted in spring or early summer. It can flower for up to 6 weeks as long as there are 12 or more hours of sunlight per day.

Buckwheat

Buckwheat is a fast-establishing warm season crop that can be utilized in a wide array of mixtures to suppress weeds by getting the soil covered quickly. If you need a workhorse to attract beneficial insects and pollinators, buckwheat fills this role exceptionally well. Rapid flowering and seed set provide a valuable source of food for wildlife. Buckwheat is also a very valuable phosphorus source as its root exudates can extract phosphorus from the soil that is not available to many other crops. When cycled, this phosphorus is then available for the next crop.

Sunflowers

Black oilseed sunflowers are renowned for their extensive and prolific root system and their ability to soak up residual nutrients out of reach for other commonly used covers or crops. Because insects are attracted to their extra floral nectaries and the bright colors of sunflower heads, pollinators and beneficials such as bees, damsel bugs, lacewings, hoverflies, minute pirate bugs, and non-stinging parasitoid wasps are often found in fields of sunflower and in following crops. With their upright growth and well anchored root system, sunflowers act as a trellis for surrounding vining/climbing cover crop plants to reach sunlight. Because sunflowers can add significant biomass production in just a short growing season, they can also serve as additional forage for livestock and are preferentially grazed when younger. For less than $1 per acre, sunflowers should be a part of almost any cover crop mix.

Warm Season Broadleaves	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Sunflower (Black Oil)	8,000	28	Excellent	Good	Good	Good	Inexpensive taproots
Okra (Clemson)	7,200	32	Excellent	Excellent	Good	Fair	Very deep rooted
Squash/Pumpkins/Melons	4,000	32	Good	Good	Excellent	Poor	Fast growing
Safflower (Baldy)	15,000	24	Excellent	Good	Excellent	Good	Spineless and grazable
Buckwheat (Mancan)	18,000	32	Good	Good	Fair	Poor	Very fast growing

Cool Season Broadleaves	Seeds Per Pound	Cold Kill °F	Drought Tolerance	Biomass Production	Forage Quality	Salinity Tolerance	Comments
Flax (Golden)	80,000	20	Good	Good	Poor	Fair	Great host for mycorrhizal fungi
Sugar Beets - Non GMO	10,000	25	Good	Fair	Excellent	Excellent	Great for grazing
Phacelia (SuperBee)	225,000	25	Good	Fair	Good	Poor	Fantastic pollinator attractor
Chicory - perennial (Endure)	400,000	-10	Excellent	Good	Excellent	Fair	Mineral accumulator
Plantain - perennial (Boston)	200,000	-10	Excellent	Good	Excellent	Fair	Mineral accumulator
Small Burnett (Delar)	18,000	-10	Good	Fair	Excellent	Fair	Deep rooted forb

Chart Key: Poor | Fair | Good | Excellent

A practice that was once a staple of intelligent crop rotation prior to World War II was including a short term (five years or less) pasture planting of perennial grasses, legumes, and forbs - what English agriculture terms a "ley crop". Before there was such a thing as cheap nitrogen fertilizer, herbicides, or insecticides, it was considered almost an essential practice to occasionally return cropland to pasture. This practice had many advantages. First was to provide a pool of available nitrogen that could maximize the yield of a corn crop. Second was to restore soil organic matter and soil aggregation. Third was to reduce the prevalence of diseases, insects, nematodes, and weeds that afflict crops. The greater plant diversity and habitat found in a pasture attracts many insect predators, such as spiders, birds, and predatory insects to help control outbreaks of insect species that migrate in from other areas, such as cutworms.

An example of a crop rotation that includes a ley crop might be four years of a grass & legume pasture, followed by corn to reap the benefits of the nitrogen credit from the legumes, followed by a rye cover crop, then followed by soybeans, then followed by wheat, followed by a sorghum-sudan pasture crop, which is terminated in early September and the pasture sod is re-established. If weeds have not become an issue and depending on the economics, this could go back to corn-beans-wheat for a second rotation before coming back to sod.

The beauty of ley crops in a crop rotation is that all these benefits (greater soil fertility, better water availability, fewer weeds, fewer insect pests, fewer diseases, fewer nematodes) come as free byproducts of the production of pastured livestock on these acres. What would be the cost of fertilizer, herbicides, insecticides, irrigation water, fungicides, and nematicides that are no longer necessary when a ley crop is included in a crop rotation? Better yields with less input cost is a great strategy to maximize profit!

Short Term Sod, Long Term Benefits

If the long-term goal is not livestock production on native perennial plants, but rather relatively fast soil improvement at the least cost, then a short-term sod mix might be the answer. This is a relatively economical mixture of fast growing perennial plant species that will grow for 3-5 years. Grasses like orchard grass, tall fescue, perennial ryegrass, prairie bromegrass, or festulolium are good fits. Perennial legumes, such as alfalfa, red clover, and white clover, are good choices but will require some grazing management. Non-bloating legumes like sainfoin and birdsfoot trefoil are also good options. Forbs like chicory, plantain, and small burnett should also be included as they establish quickly and have relatively low seeding rates. The value of this approach is that it makes it much more feasible to get a high percentage of the farm rotated to sod as soon as possible at the lowest cost possible, so that as much of the farm as possible enjoys the soil improving benefits of a perennial sod crop. Generally, a perennial mix like this will run $60-$80 per acre which is $15–$20 per year if left in production for four years.

Photo by Brett Peshek

Alfalfa, yellow clover, and red clover grow in harmony with perennial grasses in this ley mix. Grass production will be higher due to the legumes and the high nutritional content.

Forbs: The Forgotten Third Component of Pastures

In the 1950's, the introduction of the herbicide 2,4-D ushered in a new era of pasture management, in which producers were able to selectively eliminate "weeds" in pastures and create nearly pure stands of grass. We soon found out that a pure grass stand was not as productive as a pasture with mixed, diverse vegetation. We first attempted to improve productivity with nitrogen fertilizer, which helped, but found that animal performance was not as good as on a mixed pasture. Interseeding legumes can improve pasture nutrition, but the more productive legumes like alfalfa also carried a bloat risk. However, for more than a century there has been a small group of pasture enthusiasts who have been advocating the inclusion in pasture seedings of a little used class of pasture plants: forbs, or herbs as others call them.

Ecologists regard weeds as a sign that there is an unfilled niche; in other words, they are an indicator that there is sunlight, moisture, or soil resources that are not being exploited by what we have planted. The only difference between a weed and a forb is that if livestock eat it, we call it a forb, and if they don't we call it a weed. If weeds thrive in a pasture situation it is a good sign that some forb will also be successful, as long as proper grazing management is applied. Selected forbs are much higher in mineral content than either grasses or legumes, and many contain chemical compounds that boost animal performance, including some that help prevent legume bloat. In addition, if forbs are included in a pasture seeding, they fill the niche that would otherwise be occupied by weeds, and therefore suppress weed encroachment.

Some of the more valuable pasture forbs include:

Chicory is a perennial forb that has gained quite a foothold in pasture circles. Compared to other plants, chicory contains relatively high levels of minerals such as potassium, calcium, magnesium, sulfur, zinc, and sodium, which are necessary for animal health. Chicory also contains compounds that reduce bloat and reduce intestinal parasitic nematodes. It has very deep taproots and seems impervious to soil compaction. Livestock find it very palatable and the foliage is highly digestible and high in protein (30% or higher), until the plant bolts (forms a flowering stem) when it becomes far less desirable. It is one of the highest yielding pasture species available, comparable to alfalfa in yield if there is sufficient fertility.

Plantain is a perennial low-growing forb that may be even more winter hardy and indifferent to compaction than chicory. It is rapidly gaining popularity, and the people who use it love what it does for both soil and livestock. It is very palatable and nutritious, has a high mineral content, and regrows rapidly after grazing. It contains strong antimicrobial compounds which help animals fight off infectious diseases, and functions in the rumen similar to ionophores like rumensin and bovatec, increasing animal feed efficiency.

Burnet is one of the most drought tolerant forbs, and is unusual among plants in that it retains its nutritive value at all seasons and growth stages, even in winter. This is a valuable characteristic to livestock, but also to wildlife. There are stories of deer pawing through deep snow to eat still-green burnet plants in midwinter.

These plants are some of the absolute best plants available for breaking compaction. Often the best compaction remedy involves the seeding of a forb-rich temporary pasture, inoculating the seed with mycorrhizal fungi, and grazing it for a year or two. The action of the forb roots, the grass roots, the mycorrhizal hyphae, and animals such as dung beetles and earthworms act to penetrate and loosen the tightest, heaviest plowpan.

Including a few forbs in a pasture seeding can make the pasture more productive, more nutritious, and make the animals grazing it healthier. Forbs can also have a great benefit upon the soil itself, deepening the root zone and alleviating compaction.

Our Team

A clear Mission and identified Core Values are critical for any company or organization that wants to grow and not lose their way in the midst of growth, competition, and conflict. We have spent a great deal of time identifying these critical elements for Green Cover Seed. We want to share them with you, and encourage you to consider what your personal Mission and Values are.

Our Mission

To help farmers and ranchers regenerate God's creation for future generations.

Value Statement

Green Cover Seed strives to honor and glorify God through our business ethics and practices, and to follow the example of Jesus Christ when interacting with customers and employees.

Core Values

Our Core Values that guide and direct us are:

- Do the Right Thing *(Integrity with accountability)*
- Treat People Right *(The Golden Rule in action)*
- Family Matters *(People before profit)*
- Teamwork *(Synergy through cooperation)*
- Always Growing *(Both people and soils)*

We have grown significantly during our first eleven years, but the people that make up the Green Cover Seed team have been and will always be the most important.

Almost everyone here works in more than one area, but here is where we spend the majority of our time!

**Years of service in ( )*

Sales Team: L to R: Colten Catterton (7), Dale Strickler (4), Noah Young (8), Jakin Berns (9), Keith Berns (11), Brett Peshek (5) Not Pictured: Scott Ravenkamp (2), Davis Behle (1)

Outside Operations: L to R: Jeremie Trew (4), Sam Portner (5), Caleb Berns (9), Joe Melnick (1), Jared Hynes (1) Not Pictured: Rick Pendleton (6)

Inside Operations: L to R: Jonathan Jones (1), Ian Berns (2), SynDee Wulf (2), Jim Gaffney (1), Joshua Berns (7), Joseph Kirchner (2), Heath Zuellner (1), Glen Brumbaugh (2) Not Pictured: Douglas Hyler (5)

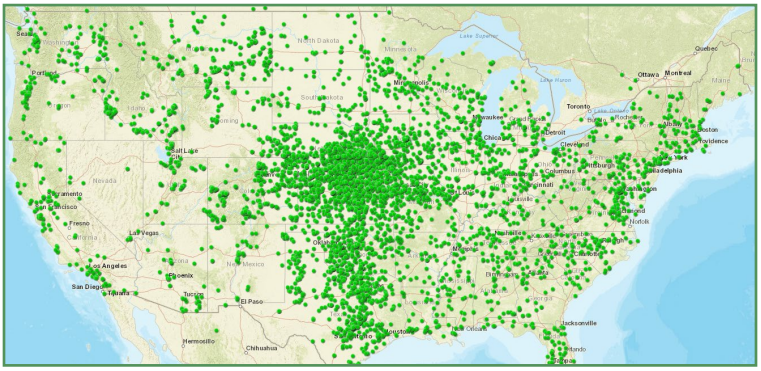
Service Team: L to R: Teri Andersen (3), Adam Jacobus (6), Carli Shuck (2), Jon Holl (9), Doris Zuellner (2) Not Pictured: Adrienne Jacobus (6)

Production Team: L to R: Shaun Wiley (1), Jonathan Ellis (9), Troy Steiner (5), Brian Berns (11)

Maintenance/Construction Team: L to R: Luke Sheltrown (1), Tim Hinrichs (2), Victor Alvarez (2), Travis Berns (8), Joe Stayner (3)

Shipping

Green Cover Seed is a leading national source for cover crops and forages, having shipped seed to more than 10,000 customers in all 50 states and most of the Canadian provinces. While the majority of seed is shipped to Nebraska, Kansas, Iowa, Missouri, Colorado, Oklahoma, Texas, South Dakota, North Dakota, and Montana, we have sold significant quantities of seed to many other areas.



Because we carry so many different cover species and specialize in custom mixes, we are able to meet the specific needs of customers across the entire country. We have even shipped multiple pallets of seed to Hawaii and across the border into Canada.

Whether we are shipping a pound, a pallet, or a bulk semi load, we strive to provide each customer with the best shipping method for their situation. Being well-connected with freight companies, and having our own trucks, we are able to move seed throughout the country at a fair price.

We run seasonal routes with our own trucks in Nebraska, Kansas, Iowa, Missouri, Colorado, Oklahoma, Texas, South Dakota, North Dakota, and Montana. We have excellent flat-rate pallet shipping rates in Nebraska, Kansas, Iowa, Missouri, and Northeast Colorado. We also have competitive national rates through FedEx Freight and other major carriers.

There are many variables in calculating shipping costs. Please call or email us for the most accurate shipping quote for your seed order. Contact information can be found on the back cover of this guide.

Infrastructure

High-quality seed standards are achieved by growing, storing, and conditioning much of our seed supply through our own operation and facilities. With our expanding network of contract growers, Green Cover Seed is able to provide customers with quality seed at an affordable price. We are contracting seed production with growers in Nebraska, Kansas, Colorado, Missouri, Oklahoma, Texas, Florida, South Dakota, Montana, Idaho, Oregon, and Canada.

We have built more than 20,000 square feet of warehouse and production facilities as well as bulk storage for more than 500,000 bushels over the past 9 years, and more storage and automation is being planned for future expansion.

Q-Sage Seed Cleaner

Our Q-Sage seed cleaner utilizes state-of-the-art technology and can condition 500 bushels of seed per hour through its 5 ½ screen shoes. Coupled with a debearder and a high-capacity gravity table, quality will not be sacrificed for the sake of productivity. This cleaning facility allows us to have quick processing times for summer-harvested cereal crops for late summer or early fall plantings.

Custom-Built Mixing System

At Green Cover Seed, we take pride in our commitment to design custom cover crop mixtures for each customer to meet their individual goals and needs. While this is good for the customer, it is the least efficient and most labor-intensive method to manufacture a product. To offset this, we have invested heavily in a custom-built mixing system that has the ability to blend up to 12,000 pounds per batch and allows us to work on three batches at a time. We can simultaneously bag one batch, mix a second batch, and weigh out a third batch. Bulk automation from twelve Meridian bins allows for higher efficiencies in the mixing process. A high-capacity toting and bagging system, as well as a bulk holding tank for mixes, increases productivity and reduces the amount of time needed to mix and process large orders.

Bulk Seed Handling

The key to efficiently handling and mixing 12,000,000 pounds of seed per year is our pod of twelve Meridian cone-bottom bins and KSI conveyors. This 60,000 bushel system is computer-controlled through a custom-built and programmable logic controlled (PLC) system that is self-correcting and self-adjusting to ensure accuracy.

This system allows us to handle bulky cereals and large-seeded legumes with precision and efficiency. We hope to be able to add another 40,000 bushels of capacity to this system to handle future volume increases!

BINMANAGER®

IntelliFarms BinManager

Green Cover Seed has invested in the IntelliFarms BinManager system that dries, cools, and even re-hydrates seed to optimum-quality levels for maximum germination. Each type of seed is analyzed and the BinManager system is custom programmed to keep the seed in the best condition possible.

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