The Purpose of This Guide

At Green Cover, our mission is to help people regenerate God's creation for future generations. As producers who make our living from the abundant resources with which God has blessed us, we should be the most adament 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, 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 educating people about soil health, and providing them with as many tools and resources as we can. This Soil Health Resource Guide is dedicated to that end.

We recognize 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. To some, this guide may be a reinforcement for what they already know; to others, it may be the first step in their journey towards healthier soils. This is by no means an exhaustive soil health resource; rather, it is intended to be a concise summary of soil health concepts, and a gateway to further learning.

Think of this guide as seeds that can sprout and grow into deeper understanding if you will, but plant them. We strive to have significant new content every year. Fortunately, we have all of them available on our website.
The Importance of Context

What would a world without context be like? Navigating a world without context is like trying to find your way out of a dark room. It’s disorienting, confusing, and problematic. Information is important, but knowledge is information in context, giving us a way to accurately and effectively connect all of the dots in any given situation. Context is everything that exists outside of a specific idea, thought, event, or situation. Context includes the circumstances—the situational factors—that can help us form specific ideas, solve problems or recognize situations that may spiral out of control.

Unfortunately, most of us ignore context in our day-to-day lives and management decisions. It is easier to maintain a sense of simplicity and order that way. It is easier to reduce our information and circumstances into smaller, singular events versus viewing our world in holistic, multi-dimensional, interconnected ways. We often ignore the bigger picture because by doing so we believe we can “solve” a problem quicker, move on, and forget it ever happened. However, this kind of thinking stifles our thinking and blurs our perspective.

In his book, Situations Matter: Understanding How Context Transforms Your World, Sam Sommers writes, “Context has a dramatic influence on how we think, how we act, who we are as people and how we impact our environment.” It is important for farmers, ranchers, and all humans to recognize that our actions are influenced by our ecological, cultural, social, and financial context.

Giving Soil Health Principles Context

In the last two decades, soil health educators have taught five basic ecological soil health principles that are based on biomimicry (to mimic life). All-natural, healthy soils function with five principles that: limit chemical, physical, and biological disturbance; keep the soil covered; add diversity of plants and insects; keep a living root in the soil as long as possible; and integrate animals into your system (see following illustration). These self-healing, self-organizing, and self-regulating principles enable ecosystem health and functioned long before humans were on earth.

As farmers and ranchers become more conscious, more observant of the ordinary, and more self-aware, the more context plays a critical role in understanding our relationship to the natural system. From a human perspective, without the principle of context, the other five principles have no purpose. Humans are deeply interconnected to the natural system—a relationship that cannot be separated. Yet our western mindset wants to isolate, delineate, and reduce our relationship with nature—absent of context. This axiom brings out this point more clearly: “The problem with ecologists—they separate the human from the natural system. The problem with economists—they separate the human from the ecology.” This thought process creates a world of confusion.

For this reason, the Soil Health Academy and Understanding Ag, LLC recently added “context” to the original five soil health principles. The principle of context gives farmers, ranchers, and agriculturists a framework to understand human nature and to be more situationally aware overall. Context helps us understand our ecological, economic, community, and spiritual situations that may prevent us from healing our soils on our farms or ranches. While not intended to be definitive or exhaustive, the following list provides an overview of some of the ways you can consider context in your farming and ranching operations:

**Ecological Context**

- How much moisture do you have? Without moisture, soil biology does not function, no matter how healthy your soil is.
- Nature uses the energy it needs and relies on freely available energy. Does your ranch or farm capture enough sunlight, or does it run on ancient sunlight (gas, diesel, etc.)?
- Do the crops or animals fit and function in the local environment? Example: Are you farming out of ecological context? Are you growing dryland corn in Western Kansas with very limited rainfall? Have you adapted your animals to your local environment? Can the type and shape of animal function in your local environment?
- Nature recycles all materials. Does your farm or ranch? Example: Take a waste product like grain spilling to feed hogs.
- Nature rewards cooperation. Is your farm or ranch functioning in cooperation like nature?
- Nature functions through diversity. Does your ranch or farm maximize diversity?
- Is your farm or ranch locally attuned and responsive to your area? What local vegetation or animals thrive in your area?
- Nature builds using abundant resources, incorporating rare resources only sparingly. Nature is efficient and does not waste energy or resources. Every organism has purpose. Does your ranch or farm curb excesses within?
- Nature uses chemistry and materials that are safe for living beings. Does your farm or ranch?
- Nature is locally attuned and responsive. Is your farm or ranch locally attuned and responsive? Are you adaptive in your management?
- Does your ranch or farm run on information? Do you have a basic understanding of ecology? Do you observe and understand the patterns and principles of nature? DNA is information. Are you using the correct breed and type of animals in your operation?
- Is farming or ranching in nature’s image your goal, or does the local community form your mindset and subconsciously set your goal for your operation?
- Are you socially conditioned by your local education and experience?
- Did you learn a majority of what you know about farming and ranching from your family and friends?

**Economic Context**

- Do you operate on borrowed money? To what extent do your creditors restrict or adversely affect your decision-making ability?
- Nature is resilient to acute disturbances. Is your ranch or farm resilient to ecological and economic disturbances?
- Nature provides mutual benefits. Does your ranch or farm have multiple streams of income? Do you provide just one product or service?
- Nature tends to optimize rather than maximize. Do you focus on yield or profit?

**Spiritual Context**

- What is your spiritual understanding about earthly stewardship?
- What is your “Why?”
- What is the spiritual mindset of your local community?
- What is your religious background and experience?
- What you believe impacts your context.

**Summary**

In life, context informs everything around us. Understanding how the world works and how people act comes down to context. A world without context is meaningless and lifeless. Context, on the other hand, provides design and purpose.

In short, context is critically important, and it comes into play in more areas of our lives than one might initially think. By paying more attention to context, we can better perceive the world around us, connect all of the dots, and make better decisions in our lives and in our farming and ranching operations.
Keep the Soil Covered

When you look at a piece of land, there is one visual indicator that the water, nutrient, and biological cycles are not functioning at optimal levels: bare ground. That is why “Keeping the Soil Covered” is often listed as the first principle of soil health.

The water cycle is directly and indirectly impacted by soil cover in many ways. When water falls from the sky, or irrigation systems, it either lands on bare soil or it lands on living or dead plant materials. Landing on bare soil can cause small particles of soil to dislodge. These dislodged particles are prone to water erosion,flowing over and dislodging other soil particles as they go. You can see evidence of this in many fields after a rainstorm. Gullies that are cut from running water is a good example of this.

Fine soil particles that don’t get washed away settle into soil pores and plug them. This directly decreases the soil’s ability to infiltrate water, and increases water erosion. Evaporation is also decreased when soils are covered. Studies by KSU and UNL indicate evaporation can be reduced by 30-50% under fall residue cover. An extra 2-5 inches of moisture in the soil profile during the growing season could be the difference between a crop harvest or a crop failure.

Once soil cover is established and biological communities begin to thrive, extra effort will be required to maintain a balance between the two. Soil biota can cycle several tons of carbon per acre every year. While this is an impressive task, it must be managed to improve soil health. It is easy for nitrogen to be tied up in microbe populations as they consume carbon sources. It is also easy for microbes to run out of carbon sources in fields with low residue levels, leading them to consume soil organic matter. When this happens, it can collapse soil structure, negatively impacting water and nutrient cycling. To avoid negative impacts, it is essential to budget for carbon in soil health management systems. Planning crop rotations, forage crops, and cover crops with carbon-to-nitrogen levels in the 24:1 range will provide microbes with the optimal diet. If your goal is to increase carbon levels in the soil, aim for a higher C:N ratio.

If you want to improve the water, nutrient, and biological cycles in your soils, then the most important step that you can take is to follow the first principle of soil health and keep the ground covered year-round.

Diverse soil biology drives the nutrient cycle and is also impacted by bare soils. Not only do plant residues provide protection from soil erosion, they also provide food and shelter for soil biota. Surface and subsurface residues provide structural habitats where soil organisms live and reproduce. Bare soil temperatures can reach more than 160°F on a sunny summer day, hotter than most soil biota can function or survive. Residue shade the ground, keeping the temperature in the upper 80-90°F range, optimal temperatures for soil organisms. Residue mulch that decreases evaporation also keeps soil moisture levels in the optimal range for soil biota.

When environmental conditions are optimal, biological communities that cycle nutrients can flourish. Earthworms drag residue into their soil channels and consume them, depositing nutrient- and biostimulant-rich die or are eaten by other organisms, organic nutrients contained in their bodies become available to plants. This cycle repeats itself constantly, so long as environmental conditions are right.

Soil disturbance can be the result of chemical, biological, or physical processes, but all forms of disturbance diminish habitat for soil microbes and result in a diminished soil food web. Chemical disturbances occur with the overapplication of synthetic fertilizers and pesticides, and when we substitute chemistry for biological functions, we disrupt the symbiotic relationships between fungi, other microorganisms, and plant roots.

Biological disturbances, such as long fallow periods and overgrazing, limit the potential and the ability for plants to harvest CO2 and sunlight. When plants are not allowed to function properly, the soil and the soil biology suffers because of increased erosion exposure, increased soil temperature, and decreased root growth and root exudates which build both soil structure and biological communities.

In nature, physical soil disturbance is always the result of catastrophic events such as erosion, earthquakes, or glaciars. In a farming system, tillage is also traumatic as it breaks open, bare, and compacted soil that is destructive and disruptive to soil life. Tillage disturbance can lead to the following negative soil impacts.

Erosion
Broken and exposed soil is susceptible to both wind and water erosion. Tillage not only breaks down soil aggregate structure which leads to erosion, but also severely reduces soil residue cover which further exposes soil to erosion.

Compaction
A typical soil is approximately 45% mineral (sand, silt, and clay), 5% soil organic matter, 25% water, and 25% air. The water and air portions exist in the pore spaces between the soil aggregates. Over time, tillage implements reduce and remove the pore spaces from our soils, restricting infiltration and destroying the biological glues which hold our soils together.

Minimize Soil Disturbance

Tillage physically breaks down soil aggregates and destroys root and earthworm channels, which makes it difficult for water to infiltrate and leads to ponding water, excessive surface saturation, and soil surface crusting.

Reduced Infiltration

Minimize Soil Disturbance

By Becky Ravenkamp

Becky Ravenkamp is a soil health advocate working to improve soil health and farm profit productivity. Having improvements on the family farm after implementing soil health practices have contributed to positive experiences and information. She spent eight years organizing conservation conferences and events for non-profit organizations in Colorado and Kansas. Now she runs production on the Roze Creek Watershed Coordination for the Lisa J. Clark WWOD and as an Executive Director for Health First.

Organic Matter Depletion

Tillage physically mixes soil organic matter (carbon) with excess oxygen and the result is a “burning off” of organic matter and the release of excessive carbon dioxide into the atmosphere. Long histories of tillage have led to significant reductions (50-80%) of soil organic matter levels across the majority of the world’s arable land.

Limiting soil disturbance is one of the most important things that any producer can do to protect, improve, and regenerate the soil. As stewards of the soil, it is our job to protect our soils from any unnecessary chemical, biological, and physical disturbances.

Cover crops can help minimize all three types of soil disturbance. When weeds are suppressed by covers, chemical disturbance is reduced. Growing cover crops keep the soil biota alive and thriving which eliminates biological disturbance. Cover crops can drastically reduce physical disturbance by reducing erosion, breaking up compaction, increasing infiltration, and adding to the organic matter of the soil.

By Keith Berns

Keith combines over 20 years of no-till farming with 10 years of teaching Agriculture and Conservation. In addition to his 2,000 acres of irrigated and dryland crops, he is involved in a water management project, and he has 25 years experience with over 100 different cover crop types and hundreds of varieties into various rotations. He has learned a great deal about cover crop growth, nutrient rotation, erosion prevention, and grazing utilization of cover crops. Keith was honored by the White House as a 2010 Champion of Change for Sustainable Agriculture and Climate-Smart Agriculture. Keith also developed the Sustainability Compass® one of the most widely used cover crop selection tools on the internet. Keith has a Masters Degree in Agricultural Education from the University of Nebraska, and teaches on cover crops on soil health science. Keith has worked in over 30 states and 15 countries per year to various groups and audiences. Keith also was appointed by Nebraska Governor Pete Ricketts to be part of the National Healthy Soil Task Force and held the privilege of serving as the chairman.

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Maximizing Biodiversity

Biodiversity | bīōdi vərəsədē | noun
The variety of life in the world or in a particular habitat or ecosystem.

Living in the Great Plains region of the United States, the soil beneath my feet developed due to a wide variety of plant species. In particular, the Tallgrass Prairie once covered 170 million acres of North America containing upwards of 500 unique plant species. Still, within a generation, most had been transformed into farmland consisting of only a handful of plant species. Today less than 4% of the Tallgrass Prairie remains intact, mainly in the Kansas Flint Hills where I live. Loss of biodiversity and degradation of ecosystem services can result from degenerative farming practices, of which many are still utilized today.

But there is hope! As defined as a “variety of life,” biodiversity in an agricultural context is the variety and variability of animals, plants, and microorganisms, at the genetic, species, and ecosystem levels, which are necessary to sustain critical functions of the agroecosystem, its structure, and processes. Maximizing or increasing biodiversity is core to any operation seeking to improve soil health, become more resilient to a changing climate, and reduce inputs for profitability. Regenerative agriculture seeks to mimic nature's method and apply it to farming systems by increasing biodiversity to build a healthy ecosystem with higher productivity.

Living Roots as Often as Possible

There are many sources of food in the soil that feed the soil food web, but there is no better food than the sugars exuded by living roots. Our perennial grasslands consist of cool season grasses, warm season grasses, and flowering forbs. Consequently, adaptable plants are able to grow during the cool spring and fall weather, as well as the summer heat, allowing for a continual live plant feeding carbon exudates to the soil food web during the entire growing season. Our cropland systems typically grow cool or warm season annual cash crops, which have a dormant period before planting and/or after harvest.

It takes all kinds of kinds. Understanding the importance of biodiversity within an agroecological sense has helped me appreciate the human side of the regenerative agriculture movement. For humans, as a species, to overcome the loss of biodiversity within farming systems, we will need to lean on the experiences and wisdom of many. This is why I am passionate about supporting initiatives that bring more women leaders into the soil health movement. Just like the soil food web, we need all kinds of kinds contributing to the advancement of the health of all people. Through my work with Great Plains Regeneration, we support and facilitate scholarships for women and historically underserved farmers and ranchers, including small-acre farmers, socially disadvantaged farmers, and veteran farmers. Through this lens of biodiversity, it gives me the greatest hope for the future of our planet.

By Jessica Gnad
Currently blurring the line between garden and art, Jessica Gnad’s path to soil health started with a curiosity about healthy food options in rural communities. She is a dedicated soil health advocate with more than a decade of experience in the food, farm, and farming industries. She combines deep industry knowledge with experience and leadership to help guide campaign development, product launches, and content strategy for news media publications and event planning. Local food movements and other regenerative community campaigns, Jess is the co-founder and Executive Director of Great Plains Regeneration.

By Jay Fuhrer
Jay Fuhrer is a soil health specialist employed by the Soil and Water Conservation Service in Bozeman, MT. He has spent the last 30+ years working with cropping systems, grazing systems, cover crops, and agroforestry. Jay also has an extensive background working with groups and entities such as soil and water conservation districts, national and international soil health organizations, watershed, farm organizations, urban groups, and more. Recently, Jay spent his time at the Menokin Farm reimagining soil disturbance, adding soil carbon, maximizing plant diversity, maintaining living roots in the soil, and integrating livestock.

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Livestock Integration

Integration of livestock back onto the land is an extremely important part of the soil health system, but is often the most overlooked or ignored principle. Grazing ruminant animals on our fields has benefits that we simply cannot mimic in other ways. Our deep, rich prairie soils were built as a result of large herds of animals grazing the landscape. Almost every acre had livestock integration until settlers came in and started to push out the wild bison herds in order to till the soil.

Most people associate animal impact on soils with compaction, but that does not have to be the case when done properly. Kansas State University has done numerous studies on the effects of livestock in cropping systems and the potential of compaction. What they have found is that in a system that uses tillage before incorporating livestock, the animals will make a mess with pugging and compacting because there is no soil structure to help hold them up. Conversely, no-till systems with cover crops exhibit very few negative animal performance or soil quality issues because of the enhanced soil structure holding the animals up. The studies showed that in good soils, the compaction layer caused by livestock rarely reached past three inches, and that no-till soils had a slower compaction rate. In most soils, the decompaction of the annual freeze/thaw cycle will more than offset any compaction caused by grazing.

Owning animals can seem daunting to row crop farmers in some parts of the world. But the principle of integrating livestock does not mean that you must be the owner of the animals. Custom grazing another producer’s livestock is a viable option. Custom grazing non-owned cattle is a viable option. Just make sure that the person managing the cattle understands the principles that make grazing and livestock incorporation a blessing and not a bane!

Proper fencing and water systems are key to making the system work. The design and implementation of infrastructure may seem daunting, but there are many resources on the internet showing modifications that can be made to more easily add livestock to your operation. It also does not matter if the animals are cattle, sheep, goats, hogs, or chickens. The key is to get animals on the land to help build soil health!
The Problem
The winter rains at the speed of smell when you are a kinetic farmer like I am. I spend lots of time with my grandpa in his pickup, remembering of days gone by. I love to ask him to paint a picture of how a particular field looked 50 or 60 years ago when he was an engaged young farmer. He describes how a 100-acre field used to be 10 or 15 smaller fields with barns, chicken houses, and pasture. It produced the bacon, the eggs, and the toast.

No Fences
By 1990 “No Fences” wasn’t just Garth Brooks’ best-selling country album, it was the landscape of the countryside. You could literally watch your dog run away for days. I was 10 years old and just tall enough to reach the clutch on our IH 3588 tractor, so my dad gave me the job of working the dirt. I missed the plow days by just a few years, but I spent thousands of hours watching my dad turn over the dirt through the dirty glass. He had worked hard to remove every fence post on our 3,000-acre farm. We thought we were getting more and more efficient with every 300-acre mega field we created.

Consolidation
Livestock has become consolidated to just a handful of farms in each county. Thousands of head under one roof. Barn after barn on the same farm. My farm produces 25,000 300lb pigs to sell to market annually. It takes 5,000 acres on a good year to feed these pigs. That’s 5,000 acres of grain that extract copious amounts of nitrogen, potassium, phosphorus, and sulfur from local farmers. Over 80% of the tillable acres in my county produce grain that feed livestock; however, only 4% of our acres have manure applied to them. These acres for the most part do not revolve or rotate, and the result is a dead-end road.

Loss of Independence
What has manifested over the past 50 or 60 years under the radar is a gradual loss of our independence. The suppliers of our inputs and the buyers of our products have control. The buyers leverage the fact that we must have their products to produce a crop. When we tear down our fences, the biggest casualty was soil health. The grain that we grew was sold by farmers, ranchers, and supporters who are dedicating their lives and livelihoods to this end as well. As our friend Jimmy Emmons says, "Long live the soil!"

Introduction to Regenerative Agriculture
"Regenerative agriculture" is a term that is widely used by everyone from farmers to consumers to politicians, but what does it mean? A 2020 study published in Frontiers in Sustainable Food Systems looked at how the term "regenerative agriculture" was used in 229 scholarly articles. The study found that while there was not a consistent definition across the board, there were five main regenerative principles that were widely agreed upon:

» Improving soil health.
» Increasing biodiversity.
» Increasing carbon cycling and sequestration.
» Integrating properly managed livestock.
» Improving the overall larger ecosystem as a whole.

It is a process of restorating degraded soils using practices based on ecological principles. Regenerative agriculture is a journey, not a destination. The term "regenerative agriculture" is used green to describe an ecosystem as a whole. It begins with understanding the soil, plants, animals, and human health and vitality of farm soil.

Regenerative agriculture is not a specific practice itself. Rather, proponents of regenerative agriculture utilize a variety of other sustainable agriculture techniques in combination. Practices include recycling as much farm waste as possible and adding composted material from sources outside the farm. Regenerative agriculture on small farms and gardens is often based on philosophies like permaculture, agroecology, agroforestry, restoration ecology, keyline design, and holistic management. Large farms tend to less philosophy driven and often use “no-till” and/or "reduced till" practices.

As soil health improves, input requirements may decrease, and crop yields may increase as soils are more resilient against extreme weather and harbor fewer pests and pathogens. ("Regenerative Agriculture", Wikipedia)

Originally coined in the late 1980s by the Rodale Institute, the term "regenerative agriculture" has gained new traction with the soil health movement of the last 15 years, but it is neither a new term nor a new concept. Indigenous farmers around the world have been incorporating regenerative techniques into their farming systems for generations, and many of our farming forebears routinely used green manure cover crops, crop diversity, and livestock integration as part of their farming practices. Today, we have the benefit of new scientific discoveries and emerging technologies (DNA sequencing, electron microscopes, etc.) to better understand the science behind these regenerative techniques. It is one of the great agricultural challenges of our day to merge and manage science, new technologies, and improved equipment with old-school farming practices that build the soil (see "An Agricultural Testament by Sir Albert Howard" on page 30). When we successfully do this, we will become "regenerative", and we can begin to rebuild what has been lost over the years. At Green Cover, our purpose and passion is to help people regenerate God’s creation for future generations. We are thankful for the thousands of farmers, ranchers, and supporters who are dedicating their lives and livelihoods to this end as well. As our friend Jimmy Emmons says, “Long live the soil!”

Gabe Brown puts it well when he says: "Regenerative Agriculture is an understanding that one must work with nature instead of against her.” (Green Cover Soil Health Resource Guide, 6th edition)

We also like what our friends at the Noble Research Institute have to say about the topic:

To us, regenerative agriculture is the process of restoring degraded soils using practices based on ecological principles. Regenerative agriculture is a journey, not a destination. It begins with an understanding that the soil, plants, animals and humans are all connected, meaning every decision must work with this natural system and not in spite of it. (Green Cover Soil Health Resource Guide, 7th edition)

Wikipedia explains it pretty well, too:

Regenerative agriculture is a conservation and rehabilitation approach to food and farming systems. It focuses on topsoil regeneration, increasing biodiversity, improving the water cycle, enhancing ecosystem services, supporting bio-sequestration, increasing resilience to climate change, and strengthening the health and vitality of farm soil.

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The Secret of Farmer Happiness: Regenerative Agriculture

By Dr. Elizabeth Heilman with Dale Strickler and Keith Berns

The desire to be happy is universal, yet many of us don’t take the proper steps to attain our dreams. A growing body of research has developed over the last two decades, revealing what makes people happy. Researchers have identified four core emotional needs: (1) safety; (2) good relationships with love and belonging; (3) self-esteem; and (4) justice. The happiest people have several factors in common that meet these emotional needs. These factors include meaningful, challenging work with outcomes in one’s control, strong relationships and social support, good physical health, meaningful leisure time, enough money to avoid economic stress, and a sense of being treated fairly.

Farming has the potential to provide high levels of happiness, but unfortunately most farmers don’t experience this, putting them at high risk. Compared to the general population, farmers have a 1.5 times higher suicide risk (CDC study) and the highest suicide rate of all occupations (Univ. of Iowa). Some studies show nearly a quarter of farmers experience depression (Bjornstad et al.). Farmers often isolated and become more so as rural populations decline, leading to loss of relationships and social support. Farm income is also highly variable and often due to uncontrollable factors, such as weather, international markets, and the cost of inputs. This can lead to a sense of injustice as well as an economic safety risk.

Farming has, in many cases, become a high-stakes game with millions of dollars invested and no guarantee of a return. Farming is also often an occupation that is not just a job but a family legacy, in which land is passed down from one generation to the next. Losing a farm is thus far worse emotionally than just losing a job. There is the added shame of letting our forefathers down and of not being able to pass the farm down to our heirs. This soil health resource guide describes ideas that can improve farmer happiness and emotional health, though they are seldom described as such. Much of this happiness comes from having more control over financial outcomes when spending less on inputs and having more resilience in the farming system. Gaining control is especially important for farmers living at the mercy of international corporations, fickle markets, and the weather definitely reduces stress.

Regenerative agriculture also provides a greater sense of self-esteem, competence, and meaningful work, all essential to human happiness. Instead of depleting your soil each year, you can experience the deep satisfaction of building your soils. Knowing that you have made your land better and your family economically safer through your own decision-making processes is deeply satisfying. When your land soaks up every drop of a heavy rainfall while your neighbor has erosion and water sitting on fields, you will be proud. Seeing continual improvement and knowing that your farming practices make your soils better for the next generation is a wonderful feeling.

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Humans are happier with modest levels of continual change. Using intellect, ingenuity, and intuition to build your soil and see the tangible results is a keystone of happiness and satisfaction. Regenerative agriculture requires one to be more adaptable, do more research, and learn new things, which brings excitement and anticipation. Learning about the soil microorganisms that practice integrative approaches to water conservation, fertilization, weed control, and pest control as you transition away from high-input agriculture is both intellectually interesting and emotionally satisfying. The learning and measurable progress involved in transitioning to regenerative agriculture eliminates boredom.

Meeting goals is most satisfying when goals reflect the standards and values you are committed to and believe in. Getting a good yield is always satisfying, but victory can be hollow if you know that you are degrading your soil and harming children’s future to achieve it. Industrial farming creates large amounts of greenhouse gas emissions, yet we can actually reverse climate change by increasing soil health, soil carbon and water holding capacity. Serving as stewards of the land, producers of healthy food, and leaders in creating a safe and sustainable planet are very meaningful goals.

By Dr. Elizabeth Heilman

Dr. Elizabeth Heilman is a Wichita State University Professor who researches the shaping of the future of education and moral understanding in the human experience. This includes democracy and moral understanding, diversity, poverty, and underprivilege. She believes people develop a sense of political efficacy, human connection, and responsibility to others and engage with the world in ways that address better approaches to local and global economic systems, complex issues of race, gender, class, health, happiness, social equity and ecological flourishing.
Regenerating Human Health with Soil Health

This article is a summary of Sara Keough’s presentation on the topic, as shared by Dale Strickler.

“Perhaps the most exciting insight is that regenerative farmers are the real healers of the planet. By being connected to the land, farmers can offer a holistic approach to the health of the body and the community. Sara Keough, a clinical nutritionist in Maryland, has found nutritional therapy to be highly effective in reducing the impact of COVID specifically, then it should be rich in not only vitamin D, but also in vitamin C, vitamin A, zinc, and iodine. Sara has found nutritional therapy to be highly effective in reducing the impact of COVID.

By far my favorite part of Sara’s talk was hearing case studies of her clients with severe health issues who had been unable to find relief in the traditional pill- and surgery medical world. It is quite amazing how she has been able to help so many people with a wide range of issues. It made me think of all my friends and family that are suffering from various ailments that could be helped simply through a better diet consisting of foods which were raised in healthy soils.

To learn more from Sara, watch her webinar on YouTube: Regenerating Human Health the Soil to Human Microbiome by Understanding Ag.
How Healthy Plants Create Healthy Soil

John Kempf is an entrepreneur, speaker, podcast host, and teacher. He is passionate about the potential of well-managed agriculture ecosystems to reverse ecological degradation. John believes regenerative agriculture management systems can:

- Regenerate producer profitability and create economic incentives for producers.
- Produce crops that are inherently resistant to possible infections by insects, bacteria, fungi, nematodes, and viruses, eliminating the need for pesticides.
- Produce food that can regenerate public health, with an elevated content of immune compounds that transfer plant immunity to livestock and people, providing food as medicine.
- Rapidly sequester carbon, build soil organic matter much faster than commonly expected, restore hydrological cycles, cool the climate, and reduce the water requirements of a crop.

All of these benefits and more can be achieved simply by managing soils and crops in a manner that enhances rather than suppresses biological function.

This article is a summary of John’s excellent webinar entitled How Healthy Plants Create Healthy Soils. To view this full webinar or access John’s other resources, please visit www.johnkempf.com.

For decades, it has been widely believed that healthy soils create healthy plants. Some elaborate on this to say healthy soils make healthy food which make healthy people. The idea is that it all starts with the soil. While that can be the case, it's actually much quicker and more effective to focus on plants first, noting that it is actually healthy plants that create healthy soil. The main difference between these two schools of thought is an emphasis on photosynthesis. Photosynthesis means plants are sequestering carbon dioxide from the air, converting it into sugars, and sending a significant portion of those sugars through the roots as root exudates to build soil organic matter.

Without the contribution of plants, soil would be nothing more than decomposed rock particles. But through plants and their root exudates, biology is fed, minerals are broken down, fungal systems are built, and healthy soil is created. Let’s go step by step through the following diagram.

**Step 1: Full Capacity Photosynthesis**

This is very tough to find in nature for a variety of reasons. The most common limitations include not enough moisture, not enough light, and not enough nutrients. The plants we are used to seeing in conventional agriculture are only at about 15–20% photosynthetic capacity. There are too many factors at play to think we can reach 100% photosynthesis; however, by addressing the limitations above, we can easily increase the capacity up to 50–60%. So if we go from 20% to 60% capacity, we have produced three times the sugars per 24-hour cycle. Three times the sugars does not mean you will get three times the grain yields, or biomass, or even root exudates, but it is likely that you will increase each of those at least some. The flow of those extra sugars goes to different places, depending on the stage of the plant. When the plant is working on grain or fruit fill, the extra sugars will go there. But when the plant is working on framing during its younger stages, well over half of the sugars may be released as exudates into the rhizosphere. That leads us to Step 2.

**Step 2: Bacterial Digestion**

With a greater amount of sugars from the root exudates, more bacteria are being fed, digesting extra carbon, hydrogen, and oxygen from the glucose (C₆H₁₂O₆). But what is largely absent in root exudates are the basic minerals such as calcium, zinc, magnesium, copper, etc. Bacteria need these minerals to form their bodies.

**Step 3: Mineralization**

Bacteria extract the minerals they need from the soil profile and incorporate those into their cells through the process of mineralization. As the life of bacteria is very short (often measured in hours), they soon perish, and these mineral enhanced microbial cells are incorporated back into the system, making the nutrient available to the plants.

**Step 4: Microbial Metabolite Nutrition**

The microbial cells then feed the roots and take minerals with them. When plants are able to access these microbial metabolites, they become highly efficient and start storing up reserves in the form of lipids (plant fats and oils). We see this in the field as a waxy sheen on leaf surfaces that provide resistance to airborne pathogens, but below the soil surface, lipids are also moving into the roots. On to the next part of the food chain.

If we are considering how to improve soil health as efficiently as possible, we must think about the plants first and seek to maximize photosynthesis, which is the engine that drives the soil system. Doing so not only triggers the rest of the steps in the diagram automatically, but it yields immediate economic results in the process.
We’ve long known that vitamins and minerals are necessary for good health in people. But over recent decades substantial evidence has accumulated that shows the importance of phytochemicals—compounds that plants make—in keeping chronic diseases at bay well into old age. In our new book we review the history of nutrition and highlight that defining nutrients as things necessary for growth and survival neglects the importance of other compounds that influence human health—those that modern farming practices reduced or altered in the plant and animal foods comprising the human diet. Chief among these are micronutrients, phytochemicals, and certain fats. Many serve antioxidant and anti-inflammatory roles in human physiology—as mediated by our gut microbiome. The conventional view of crop nutrition is now being reframed around biologically-mediated plant-soil interactions. Most crops form partnerships with mycorrhizal fungi that help them acquire mineral micronutrients in exchange for root exudates. Soil life also stimulates the production of phytochemicals like carotenoids and polyphenols that serve protective roles in bolstering plant health—and serve as antioxidants and anti-inflammatory compounds when we eat them. Studies over the past several decades solidly established that soil life influences mineral uptake and phytochemical production in numerous crops.

Likewise, studies over the past several decades have shown that ruminants grazing a diverse diet of living plants in pastures have different fat profiles than their brethren fed a diet of seed-based feed products. In general, grasses and shrubs have higher content of omega-3 fats than do seeds (e.g., corn and soy), which tend to be far higher in omega-6 fats. So the amount of each and balance between these physiologically distinct fats in meat and dairy products depends on the diet of the animal producing them. Based on our literature review and some direct comparisons, ruminants, pigs, and chickens grazed on living plants have substantially higher omega-3 content and a better omega-6 to omega-3 ratio.

We turn to links between soil health and human health, exploring how regenerative farming practices can enhance the nutritional quality of our food through their effects on soil life.
Economics of Soil Health on 100 Farms

Improving soil health can help farmers build drought resilience, increase nutrient availability, suppress diseases, and reduce erosion and nutrient losses. Many soil health management systems also benefit the environment by storing soil carbon, reducing greenhouse gas emissions, and improving water quality. However, investing in soil health management systems is also a business decision. While almost everyone agrees that soil health is important, not everyone agrees that it is profitable. To answer this question, the Soil Health Institute (SHI) and Cargill conducted a major research project to provide farmers with the economics information they need when deciding whether to adopt soil health practices and systems.

The SHI interviewed farmers who have adopted soil health systems across nine states to acquire production information for evaluating their economics based on partial budget analysis. In using this approach, the costs and benefits of a soil health system are compared before and after adoption of that system.

**Summary of soil health management system benefits reported by 100 farmers**

<table>
<thead>
<tr>
<th>Benefit Reported</th>
<th>% Responding Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Yield</td>
<td>67</td>
</tr>
<tr>
<td>Reduced Applied Fertilizer</td>
<td>83</td>
</tr>
<tr>
<td>Increased Crop Resilience</td>
<td>87</td>
</tr>
<tr>
<td>Increased Field Access</td>
<td>93</td>
</tr>
<tr>
<td>Improved Loan, Land, or Insurance Terms</td>
<td>41</td>
</tr>
<tr>
<td>Improved Water Quality</td>
<td>100</td>
</tr>
<tr>
<td>Protects License to Operate</td>
<td>98</td>
</tr>
<tr>
<td>Increased Soil Organic Matter</td>
<td>54</td>
</tr>
</tbody>
</table>

We are grateful to the Soil Health Institute and Cargill for conducting this study and showing that soil health practices are profitable in the short run for the producer as well as valuable in the long run for the land and the environment. The farmers interviewed for this project are clearly leading the way and therefore offer substantial opportunities for others to learn from their experiences in adopting soil health systems. With national adoption rates for no-till at 37% and cover crops at 5%, there is much to be learned, much to be gained, and much profit to be realized for those who are willing to adopt and properly manage soil health practices. We encourage you to read the full study at www.soilhealthinstitute.org/economics/.

**Project Highlights**

- The 100 farmers that were interviewed for this project used no-till on 85% (19 years average no-till experience) and cover crops on 53% of their acres (9 years average cover crop experience).
- Across all 100 farms (nearly 2,000 acres average size), soil health management systems increased net income for 85% of farmers growing corn ($51/acre increase) and 88% growing soybean ($45/acre increase).
- 67% of the farmers interviewed reported increased yield from using a soil health management system.
- Cost of production was $24/acre less to grow corn and $16.57/acre less to grow soybeans using a soil health management system.
- Farmers also reported additional benefits of their soil health management system, such as increased resilience to extreme weather, increased infiltration rates, and increased trafficability of their fields after a rain.
- 54% reported increased soil organic matter levels by an average of 1.2% due to the soil health management system. Research has shown that higher soil organic matter increases soil's available nutrients and water holding capacity, which is consistent with the reduced fertilizer application, increased crop resilience, and improved field access observed by these farmers.

**Change in net farm income from corn for 100 farms after adopting a soil health management system compared to a conventional system.**

**Change in net farm income from soybeans for 100 farms after adopting a soil health management system compared to a conventional system.**

**“Bet you feel pretty stupid now!”**

Daniel Mushrush ranches near Elmdale, Kansas, in the heart of the Flint Hills. While most of the region is native grassland, there are rich river bottomlands that are used for growing corn. After doing the math a couple of years ago, Daniel decided to stop using his river bottom for corn silage and planted a combination of alfalfa and Estancia novel endophyte tall fescue. Of course, this “radical” move caught the attention of his neighbors, as the bright green field was a stark contrast to the winter-totall-bare ground of the harvested corn and soybean fields. One spring day, Daniel entered the local morning coffee and gossip gathering place and was accosted by the group. “Bet you feel pretty stupid now because you planted all that good bottom ground to grass and now corn is $6 a bushel!” “No, I am feeling pretty smart right now, actually” “Huh? But you could be growing $6 corn instead of grass!” “Well, I use that land to graze and feed my cowherd in the winter. I used to chop silage. When corn goes to $6, the cost of seed corn, fertilizer, herbicides, fungicides, and equipment goes up. Silage costs $400 an acre to put in, and another $200 an acre to chop and put in a bunker. That's already $600 an acre. Now that I have alfalfa and grass, I don't have to buy seed corn at $300 a bag, or any seed, because the perennials last for years. I don't have to buy nitrogen because the alfalfa makes it for me for free. I don't have to buy phosphorus or potassium fertilizer, because grazing recycles all those minerals back to the soil. I don't have to buy herbicides or fungicides or insecticides, because I don't have problems with weeds, diseases or insects. And I don't have to pay a chopping bill or fire up a tractor every day because the cows do all the harvesting themselves. I get about the same tons per acre as when I raised silage, but it costs me several hundred dollars per acre less to do it. And when the river comes out its banks, my soil stays in place while a lot of your soil in the corn and bean fields washes away. So, yeah, I feel pretty smart right now.”

The coffee shop went pretty quiet for a bit while Daniel’s words soaked in like spilled coffee on a paper towel. Think about it. A typical yield of corn silage in southeastern Kansas is about 20 tons per acre, at 35% dry matter, for a total yield of 7 tons per acre. Fermentation and spoilage will take at least 20% of the stored energy, so 7 tons ends up being more like 5.6 tons of actual feed. A good perennial alfalfa and grass combination can normally produce 5-6 tons an acre, and like Daniel told his coffee shop buddies, you don’t need to buy seed every year, or nitrogen fertilizer, phosphorus, potassium, herbicide, fungicide, or insecticide, or pay for chopping and packing, or feeding equipment!

Having a novel endophyte fescue in the mix provides a forage that retains excellent nutritional value even in the dead of winter, so this mix provides feed at the exact same time as stored silage would be fed.

Though Daniel is happy with his fescue and alfalfa, he is not yet convinced that he is maximizing the potential of those acres. His stand is still young and has not yet filled in to form a solid stand; it should increase in productivity over the next year or two. It may also be possible to introduce some other species to gain some additional production. In late June, he also tried interseeding summer annuals (sorghum, sunflowers, and sunn hemp) into his fescue to try to grow some additional biomass that would persist into the winter and add some biologically fixed nitrogen as well as enhanced soil health benefits. Despite a prolonged summer drought, the interseeded crops managed to grow well above the summer growth of the fescue and added to the total amount of grazable biomass.

Comparing the costs of corn silage versus stockpiled pasture to feed cattle in the winter not only makes you realize why Daniel is feeling smart these days, but also makes you wonder why more people don’t follow his example so they can feel pretty smart as well!
Roots Build Soil Health

This excellent article is from Cover Crop Corner, an educational column put out by our friends at GO Seed. For more information or to be added to the distribution list, please email fgonzales@goseed.com.

Restoring the capacity of the soil to function is done by regenerating the soil into a vital living system. Let’s start by viewing the soil as the habitat for billions of organisms. What do all organisms need to have a healthy habitat? They need food, water, air, and shelter. When we take deliberate steps to restore the soil as a habitat, it reigns its ability to function. When the soil functions properly, it is better for all inhabitants on earth and can also yield a significant increase in farm profits.

The number one word I associate with improved soil vitality and function is roots. Soils need plants to capture carbon from the atmosphere and send it through their roots to feed the multitude of organisms that actively create structures, cycle nutrients, and regulate the water cycle. In the pursuit of soil health, perennial, well-managed, grazing systems are best. But when animals are not an option, adding cover crops is the number one management practice I consider critical to incorporate into a row crop system. Below is a taste of how cover crops improve the soil as a living habitat.

Food: Nutrient Cycling

All organisms need “eat” something, and organic carbon is key to getting soil organisms to cycle nutrients your crops need from the soil. Carbon, the primary component in organic matter, is what feeds the microbial community who provide the services of cycling mineral and organic nutrients, making them available to plants. Most of the carbon added to the soil actually comes during the active growing process, rather than from plant residue. Roughly 50-60% of the carbon that plants capture through photosynthesis is sent through their roots into the soil because it is beneficial to plant growth. Plants feed the microbes, and microbes feed the plants.

Also, 80-90% of all plant species on earth form symbiotic associations with mycorrhizal fungi, which live in and on plant roots. Again, the plant captures carbon through photosynthesis and sends it to the roots to deliver to the fungi. The fungi then grow and reproduce and since they are inside of the plant roots, this causes a massive increase in the total surface area of a root. This increases the amount of soil surfaces which the root encounters, which increases its ability to exchange nutrients and scavenge for water. The fungi also produce many enzymes which break down even more nutrients for the plant to take up.

Still another way that cover crops can impact the balance of food in the ecosystem is by reducing nutrient leaching through the soil profile and runoff over the surface. Available nutrients are taken up by the plants rather than having a negative impact on downstream aquatic species. The captured nutrients can be released in the following season during decomposition of the cover crop while the cash crop is growing. The economy of nature relies on trading of carbon so everyone can get what they need. The more carbon is exchanged through the root bank, the more the natural capital of the soil grows and the more you will be able to save in fertilizer bills.

Shelter: Physical Structure

It might seem odd to consider, but soil organisms build themselves “shelters” and in so doing create pore spaces and aggregates. Microbes exude carbohydrates, proteins, DNA, enzymes, and lipids into their immediate surroundings, that over time build a biofilm enhanced environment where microbes carry out their work. As microbes do this in the soil, the organic molecules glue mineral particles together which stabilizes pores spaces for water and gas, allows organisms to move, and aggregates the soil. Plants, worms, and the rest of the organisms living in the soil also contribute to the formation of stable aggregates by tunneling through, digesting particles, trapping them together, and pushing them around. This diversity of action and production produces a positive feedback cycle allowing the plants and micro-organisms to be better at their jobs and build more intricate underground architecture creating unique niches and shelter for organisms which enhance the soil’s ability to perform the functions that are useful for us.

A direct benefit of these organisms building their shelters is that these communities working together can alleviate compaction. Again, plants provide organic carbon to the soil organisms but also works through the direct action of roots pushing through the soil. Aggressive fibrous rooted crops like sorghum and ryegrass can penetrate tight soils which in turn allows water to penetrate the soil surface. Deep tap rooted crops like radish, sunflower, and balansa clover can drive roots deep, even through a tight clay or plow pan. The roots of the following cash crop can then move through the compaction zone which increases the total soil volume available for the plant to find nutrients and water which has demonstrated increases in yield.

Water: Cycling and Storage

Many soil microbes can go into a dormant state when the soil dries out, but for them to actively cycle nutrients and build structures, they need water. The good news is that when we take care of the food (carbon) and shelter (pores and aggregates), the water that does come will be optimized. Texture has a strong influence on the natural tendency of how soil interacts with water. However, when there is an excess of carbon, increases filtration rates and storage as well as decreases ponding and nutrients flowing out. It may seem counterintuitive that we can increase water holding and improve water movement at the same time, but we can. These multiple processes are possible when the built habitat has a variety of pore sizes and aggregates with an active microbial community. Roots, hyphae, exudates, and worm slime stabilize large pores whereas water to infiltrate into the soil and flow around aggregates and particles. Stable aggregates create many smaller pores and intricate structures, and the smaller the pore the tighter the water is held. I have measured dryland silty soils, both with and without cover crops, that had 16% and 7% gravimetric moisture respectively. This can be the difference between high and low yield in this dryland wheat system. That same soil zoned one inch of water to infiltrate in 15 seconds in the area with the cover crop and three minutes without the cover crop.

Cover crops also help capture water when they are left as residue on the surface. When rain falls, there is a lot of energy in each one of those droplets hitting the surface and that will often dislodge even well aggregated particles. Anytime a living plant or residue can break the fall of a water droplet, there is a decreased risk that the aggregates will break, and the individual particles will form a seal causing reduced infiltration. They also provide an insulation layer that moderates temperature reducing evaporation.

Closing Thoughts

At this point, I hope you are thinking more about which cover crops you are going to use rather than if you are going to use cover crops. I think the first questions to ask yourself should be related to your specific goals and challenges. Select cover crop species that have demonstrated the ability to address your production problems or complement your strengths.

Soil is the natural capital of the land. When you invest in soil health by planting a cover crop, not only are you making an impact on all of the downstream ecosystem services that are related to soil functions, but you are also forging a lasting legacy for future generations of agricultural producers and protecting your long-term investment.

By Shannon Cappellazzi

Shannon Cappellazzi is the Director of Research at GO Seed where she leads a team of scientists and students researching the world’s most essential resource: soil. Through her leadership, she has developed cutting-edge research and production technologies to help farmers grow higher yielding crops with improved soil health through innovative solutions that are sustainable and economically feasible. Shannon’s research has been featured in several publications including the cover story for the Soil Health Initiative’s North American Project Brief: Case Studies in Soil Health Improvements.
Nitrogen: The Double-Edged Sword

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 nonrenewable 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 biomolecular 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.

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 photosynthetic), 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 micromycorhizal 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.

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 irreversible 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 about 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 practices is not difficult. The 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-round 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.

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 widely popular on the United States Soil Health speaking circuit.

We at Green Cover count it a blessing to call her a mentor and a good friend.

For further information, visit www.greencover.com
What Can I Plant to Make Nitrogen for Next Year’s Corn?

The two most common questions we receive when fertilizer prices go up are, “Have you heard what they predict nitrogen fertilizer will cost next year?” and “What can I plant to reduce my need for nitrogen fertilizer?” Both are legitimate and timely questions.

At one time, all of our agricultural nitrogen needs were supplied by biological fixation from legumes or cycling biologi- cal fertility (manure and other residues). More than a hundred years ago, the German chemists Fritz Haber and Carl Bosch developed a process to create ammonia from atmospheric air (which is 78% N) and methane. Originally, this process was primarily used to produce explosive materials for use in the two World Wars. After the end of WWII, the production of anhydrous ammonia was rechanneled from making bombs to making fertilizer for growing crops. This nitrogen revolution changed how we do things in agriculture, and we have largely lost the knowledge of how to farm without synthetic fertilizers.

Given the growing need to produce food, feed, fuel, and fiber, many people rightly wonder if we can generate enough nitrogen from biological means to eliminate or at least reduce our synthetic nitrogen while remaining profitable. Thankfully, the answer is a resounding yes, but it will likely require changes in the way we grow crops to accommodate these biological processes. Since understanding the mechanisms behind the process allows the user to intelligently manage the system, let’s review a few things about biological nitrogen fixation. (A deeper dive into the scientific aspect of this process can be found in Nitrogen: The Double-Edged Sword, pages 26-27 of this guide.)

The amount of nitrogen that can be produced by a legume cover crop is directly related to the volume of biomass produced. This number will depend on many factors including moisture, temperature, soil compaction, length of growing season, mineral nutrient availability, and biologi- cal activity. While it is impossible to predict exactly how much nitrogen will be produced, some general rules can be applied.

Summer annual legumes (soybeans, cowpeas, mung beans, sunn hemp) generally fix more nitrogen per day of growth than winter annual legumes (peas, lentils, vetch, clovers), because there is more sunlight and more favorable temperatures. However, winter annual legumes can have more days of active growth due to their ability to grow in the fall, survive the winter, and continue to grow in the spring. In general, legume biomass runs about 3% nitrogen; thus, a ton will contain about 60 lbs of nitrogen. In favorable conditions (temperature and moisture), warm season legumes can produce up to 70 lbs of biomass per day, or about a ton per month.

A cover crop of summer annual legumes will fix more nitrogen the longer it grows, but 150-180 lbs is still achievable from a July planting after wheat harvest. Winter annual legumes planted in the fall usually produce the most growth (and thus nitrogen) in the spring, so the longer they are allowed to grow in the spring, the more biomass and nitrogen they can produce. Our Green Cover demonstration plots have shown that more than 70% of the nitrogen fixed by winter peas or hairy vetch will occur during the month of May. In Nebraska, nitrogen amounts of 180-220 lbs are possible when these covers are allowed to grow until late May. The amount of nitrogen that we can make available to the next crop will depend on multiple factors including C:N ratio of the cover crop, amount of time from cover crop termination until next crop need, temperature, and moisture. A general rule of thumb is that two-thirds of the nitrogen from a low carbon (C:N less than 25) summer cover will be available for next year’s corn crop, and half of the nitrogen from a low carbon winter cover will be available for the following crop. The remainder of the nitrogen from these cover crops will be available for future crops.

To utilize nitrogen fixing cover crops in a cropping system, it may be necessary to modify your rotation. Consider the ubiquitous corn-soybean rotation. Everyone is desperately seeking a legume that can be planted after soybean harvest in the fall, terminated in early April for corn planting, and produce enough nitrogen to support 2400 lbs/acre corn yields. This is not feasible, but with a few changes, it is possible to greatly reduce the need for purchased nitrogen in a corn-soybean rotation:

- Plant shorter season beans to get the fall cover established sooner.
- Plant shorter season corn so it can be planted a little later in the spring and allow the cool season covers to grow longer.
- Add a summer harvested crop to the rotation (small grain or peas) which allows a summer cover to be planted to produce nitrogen ahead of corn. Cool season legumes can still be planted right before frost to double down on nitrogen production ahead of a corn crop.
- Lengthen the rotation a year by incorporating a full year of grazed cover crops (see pages 36-39).
- Insert a few years of a pastured sod crop (such as alfalfa and orchardgrass mix) into the rotation. Research and practical experience alike demonstrate that corn following a terminated pasture sod with appreciable alfalfa content will produce maximum yields without need for supplemental nitrogen fertilizer.
- A highly experimental option is the use of perennial legumes as a living mulch system, in which corn is planted into suppressed strips of alfalfa or white clover. The legume stands regenerates year after year, providing a constant source of nitrogen. This is a strategy that requires high levels of management but can potentially yield great benefits.

Utilize free-living nitrogen fixing bacteria that can live in the rhizosphere of plants like corn or sorghum. Green Cover’s Bi-Azo inoculant features two such nitrogen fixing bacteria: Azotobacter and Azospiril- lum. This organisms will not produce large amounts of nitrogen (30-50 lbs per acre), but the cost is low (less than $4 per acre) and it does not take much extra nitrogen to pay for it. It can be put on a cover crop preceding corn or directly on the seed corn prior to planting or both. If you are deficient in nitrogen, each additional pound of nitrogen might just gain an additional bushel of yield.

Kyle Geib of northwestern Missouri is an organic farmer who was sourcing his nitrogen from expensive poultry litter. He called Green Cover looking for alternatives, and we suggested moving to a corn-soybean-wheat rotation. After wheat harvest, Kyle planted a combination of sunn hemp, cowpeas, sorghum, and sunflowers. In late August, before any of the crops or weeds could set seed, he roller crimped and drilled in a cool-season cover crop mix with oats, radishes, peas, and vetch. This mix was then roller crimped the following May during bloom, and corn was nati- tilled into the thick mulch. In a drought year when all his neighbors (most of them being conventional and able to use the yield-boosting crutches of fertilizer and herbicides) had corn yields in the 120 bushel range, Kyle’s corn made 180 bushels per acre, with no herbicides, no fertilizer, and no tillage. Not only did the heavy mulch that included legume residue provide all of his nitrogen fertility needs, it also helped retain moisture in a drought year, and helped suppress weeds, which are the usual “Achilles’ heel” of organic farmers.

Whether you are organic or not, your ears ought to perk up when you hear of someone outyielding the neighbors by 50%, and doing it while spending less on input costs.
Case Study: 200 bu Corn With No Nitrogen

“You just can’t grow good corn without fertilizer—and the more fertilizer, the more corn!” If you are a corn farmer, odds are this saying has been drilled into your brain so deeply that it almost seems like heresy to question it. We have all seen where there has been a skip in fertilizer application and the corn is pale and stunted. It is absolutely true that we need fertilizer—nitrogen in particular—to grow good corn crops in the soils and management systems in place across the vast majority of our nation’s farmed fields. But what if the soils and the management were different? Could we change our soils so that they supplied the nitrogen and other nutrients to our crops without the need for applications of synthetic fertilizer?

That was the hypothesis that Jay Young of Young Red Angus in Tribune, Kansas, set out to test with experimental strips in his irrigated corn field. On the first test strip, he applied the fertilizer his agronomy consultant called for, which was 180 lbs per acre of actual nitrogen and 40 lbs of phosphorus. On a second strip, he applied no fertilizer at all, but rather 8 gallons per acre of a compost extract made from 2 lbs of compost produced by the Johnson-Su method, which creates a compost with a high population of fungi. On a third strip, he applied 90 lbs of nitrogen, no phosphorus, and 8 gallons of Johnson-Su compost extract.

The results? When the combine rolled, the full fertility treatment test strip produced 238 bushels per acre, while the no fertilizer treatment strip yielded a lower 207 bushels an acre and blew the other two treatments away. The strip treated with a half rate of nitrogen and compost extract combined, which yielded a very impressive 242 bushels an acre and increased soil carbon sequestration while greatly improving crop yields.

Left: Corn with N applied had more seeding growth but less root development. Right: Corn seedlings with only compost extract had less above ground growth early but tremendous root system development. The soil stickiness to the roots is a sign of high soil microbial activity.

The Johnson-Su biostarch allows farmers to make fungal-rich compost aerobically without turning it. It takes about a year to make but the result is a more biologically diverse and nutrient-rich product that greatly improves the biology and nutrient availability of the soil, improves water retention capacity, and increases soil carbon sequestration while greatly improving crop yields. It is vigorously stirred to aerate it. The lack of disturbance and slow, cool decay results in a compost that is very high in fungal activity. Most agricultural soils are very low in fungi due to a long history of tillage, which tears fungal hyphae apart. Fungi are a major driver of desirable soil structure and aggregation. When soil structure improves enough that soil aggregates begin to reach a minimum diameter of 10mm (about ⅛ of an inch), something curious begins to happen. It has long been known that there are free-living nitrogen fixing bacteria (like Azotobacter and Azospirillum) in the soil, but it was always assumed that their activity was so minor that they did not really contribute much to soil fertility. But all those observations were in tilled soil largely devoid of good soil aggregation. Why is this important? Most of these free-living nitrogen fixing bacteria require an unusual combination of conditions in which to thrive: a copious amount of carbon root exudates for an energy source; and anaerobic (lacking oxygen) soil. This at first seems contradictory. Roots need aerobic soils full of oxygen to grow and produce exudates. So where exactly could these two conditions both occur? As it turns out, it happens inside of large diameter aggregates with a high level of microbial activity that uses up the oxygen as it diffuses from the outside of these large aggregates towards the center, creating an anaerobic core where these bacteria can live but also be in close proximity to roots that produce their energy giving exudates. These free-living nitrogen fixers require conditions which we have not seen in most agricultural soils until recently—a lack of tillage, a constant flow of root exudates, and a high fungal population. How much nitrogen can they produce? We honestly don’t really know. But we do know that given the right conditions they can contribute a lot more than we used to think. Dr. Richard Mullvany and Dr. Saeed Khan of the University of Illinois are currently researching this very phenomenon, and we hope to be able to learn more from their finding in a future resource guide!

For more information on these topics, check out these YouTube videos: 200 bushel corn with no nitrogen by Young Red Angus. Dr. David Johnson & Hui-Chun Su by Green Cover Seed. Why composted soils average about 0.4% phosphorus content. The top three feet of an acre (the root zone) weighs about 12 million pounds, which gives 48,000 pounds of phosphorus per acre (12,000,000 x .004). If a 200bu corn crop requires 48 lbs of P per year, then we have a 1000 year supply—if we could extract it all. Unfortunately, in most of our biologically weak cropland, we appear unable to extract any.

The second reason is that natural ecosystems have microbes called lithotrophs that literally eat rocks and spit out minerals. Why are they found in natural ecosystems but not in cropland? Let’s compare several factors between the two systems. Natural ecosystems are dominated by perennial systems, with great diversity of plants that photosynthesize and have live roots throughout the majority of the year. The root systems are also enormous; an acre of prairie may have up to 15 tons of root mass. These systems have never been tilled, so the full spectrum of soil microbes and fungi, including mycorrhizal fungi, have never been lost. Cropland, on the other hand, has had a long history of tillage and fallow, which has starved out many rhizosphere microbes and mycorrhizal fungi that depend on a living root to live. Cropland has been farmed with primarily monocultures of annual plants with small root systems for decades or centuries. A corn crop might have 3000 lbs of roots per acre, or ⅓ the amount of the prairie grasses it displaced, and that root system is only present in the soil for a few months of the year. The lithotrophs are no longer abundant in cropland because they needed the carbon-rich exudates from live roots and mycorrhizal fungi around the year to survive, and our cropland has simply not had those conditions for many of the years in which it was farmed.

We can create systems and soils with lower requirements for fertilizers by following the principles of soil health and especially by mimicking the natural ecosystem by maintaining living roots in the soil for as long as possible throughout the year.
We want to share with you a summary of a great book on Regenerative Agriculture, *An Agricultural Testament* by Sir Albert Howard. This book covers topics such as:

- The benefits of mimicking nature and natural growing systems.
- The benefits of growing multiple crops together in the same field (polycropping or interseeding).
- The paramount importance of covering the soil surface.
- Using microbiology to unlock fertility reserves in the soil.
- The mycorrhizal association: the living fungous bridge between humus in the soil and the sap of plants.
- The role of synthetic nitrogen in increased frequency of plant disease and insect problems.
- Using soil algae as nitrogen fixers.
- The benefits of compost, compost tea, and other sources of biological amendments.
- The strong link between a healthy soil microbiology and the health of the people and animals consuming the crops grown on the soil.

We think these topics are cutting-edge ideas that the "really cool" farmers started talking about only recently, but that is not actually the case. These are all topics found in Sir Albert Howard's wonderful book published in 1940! Before America even entered World War II, more than 80 years ago, these ideas were being discussed. Unfortunately, most of us have been ignoring them for as long as they have been around.

Albert Howard was “regen” before “regen” was cool. He was a plant pathologist for the British government and primarily worked in India, trying to solve problems affecting the crops there. He originally followed the practices he was taught in the university, but soon figured out that he received better results by mimicking natural systems. Howard describes how natural systems work, and how natural systems are incredibly resistant to disease while our agro-ecosystems seem so susceptible. He draws a strong link between soil humus and a healthy population of soil microbes, and between a healthy microbial population and the resistance of plants to disease. But he doesn’t stop there. He also links healthy soil and the health of people consuming the produce produced from that soil. Only now do scientists seem to be connecting the dots of information which Howard started collecting over 80 years ago regarding soil microbiology and the ability of crops grown in soil rich in microbial activity to prevent disease.

Since *An Agricultural Testament* first appeared in 1940, it has been regarded as one of the most important contributions to the field of soil rehabilitation ever published. In the preface Howard states:

> “Since the Industrial Revolution the processes of growth have been speeded up to produce the food and raw materials needed by the population and the factory. Nothing effective has been done to replace the loss of fertility involved in this vast increase in crop and animal production. The consequences have been disastrous. Agriculture has become unbalanced: the land is in revolt; diseases of all kinds are on the increase; in many parts of the world nature is removing the worn-out soil by means of erosion. The purpose of this book is to draw attention to the destruction of the earth’s capital — the soil; to indicate some of the consequences of this; and to suggest methods by which the lost fertility can be restored and maintained.”

If these 80-year-old words sound strangely familiar to you, then we strongly recommend that you read *An Agricultural Testament* by Sir Albert Howard. You will be shocked at how many of the ideas we consider new and radical are just reinventions of a wheel we have ignored for nearly a century. You can access this book for free by going to www.journeytoforever.org/farm_library.html.
One Man’s Trash Was My Treasure

To some farmers, crop residue might be the single most frightening aspect of no-till. Whether it is soybean, corn, milo, or wheat stubble, or a diverse cover crop mix, there seems to be hesitation when it comes to no-till seeding your next crop into heavy residue. The worry of how planting equipment is going to penetrate all that “trash” is a stumbling block on the route to soil health, but one that can easily be overcome. “To the untrained eye, planting into a naked, tilled field may be one of the most aesthetically pleasing sights in farming—to see bare soil with perfectly spaced row marks can give a sense of accomplishment and confidence. However, my eyes now see the shortcomings that accompany the tillage system, and I remember that planting the seed is only the first step in the production of a profitable crop.”

Last year I took over a new farm, and as a younger farmer I am willing (maybe I don’t know any better!) to take on problem fields. One particular parcel of land had laid idle the previous year, and on the edges and in spots throughout the field were thick patches of annual winter grasses. Everywhere else was either bare soil or had very little residue. I no-tilled soybeans into the field on June 6th, and planting the crop went great. Seed depth and placement seemed to be adequate for the soil conditions, and less than 12 hours after planting I was “blessed” with over two inches of pounding rainfall in 45 minutes. Normally, I love to see rain right after planting, but this was not the kind I needed. After a week of sunshine and warm days, I decided I had to go see what I had to deal with. Pulling up to the field, it looked as though somehow I had been lucky enough to capture a decent stand. However, I quickly realized I had a problem, and I learned a very important lesson about residue.

Anywhere in the field that I had planted through the patches of the winter annual grasses, including at the edge of the field drive, I had a good stand of freshly emerged soybeans. As soon as the planter left the residue and was in the bare soil, there was less than a ten percent stand at best. As I examined the soil and the seedlings (or the lack thereof), I discovered what had happened. For a sensitive emerging crop, such as soybeans, soil crusting is one of the biggest problems with stand establishment in tilled, and even no-till, no-cover situations. As the rain came beating down, the residue from the annual grass absorbed the energy of the raindrop impact and protected the fragile soil underneath. This same protective barrier of residue blocked the sunlight from quickly drying out the soil and causing the crust. The bare soil had no protection and the beating of both the raindrop and the sunshine caused a thick crust to form and prevented almost all of the soybeans from emerging.

By Zach Louk

Zach Louk is not only a Green Cover Sales Representative based out of the KJ, KS location, but also a farmer and rancher himself. Two traits for the soil and for animals, among his goals to seek synergies to regenerate his farm as part of his vision, and to go the extra mile to help others do the same.

Growing Forage in a Drought

A familiar phrase in the regenerative agriculture world is, “I wish I had started this a long time ago.” JD Alley is one of the latest people to utter it. JD and his brother, Mike, farm and run cattle in Culver, Oregon, where 2021’s historic drought has been severe.

Mr. Alley sent some photos and testimonials about how well his cover crops did this year in the face of some of the worst drought his area has ever seen, and we thought it might be a good idea to highlight his experiences. His cover mixes did surprisingly well given that they only received 3.39 inches of rain in 2021 (annual average is 11 inches) and were only able to apply 9.6 inches of water per acre, compared to a historical allotment of around 48 inches. Despite his crops receiving less than 13 total inches of moisture (and losing a lot of the water to evaporation from his sprinklers) his crops performed surprisingly well. When asked why he made the changes he did, it was another familiar refrain: “Financial difficulty.” It seems like most people only decide to make changes after their backs are against the wall, and they see that they can no longer continue to do the same old thing and expect different results. If you attend any conference on regenerative agriculture, that is a very common thread among most of the speakers. They were forced to change because they could no longer afford the same old results from doing the same old thing, but in retrospect, they wished they had changed much earlier. For the Alley brothers, the same old thing was raising racehorse-quality timothy hay. Here is JD’s story in his own words:

I was producing a very high-quality product with a premium price. I was good at it, and it brought high prices. You would think that would be a recipe for financial success, and for a while it seemed to be. I was bringing in a lot of money, but I didn’t seem to keep any of it. I was having to put out over 200 lbs an acre of nitrogen and a lot of potash to maintain hay yields, and I was having to apply a lot of water to get the yields. My soil seemed to be getting worse, too, which makes sense to me now since I was exporting all my above ground organic matter. I started trying to figure out how I could reduce my fertilizer bill, and I read somewhere that a cow produces 0.3 lb of nitrogen per day in manure and urine. It dawned on me that I already had the cows, I just needed to figure out how to make them defecate and urinate where I needed the fertility (on my crop ground). I started using summer annual grazing crops on my pivots to produce quality grazing during our rainless summers, then I followed that with winter annuals for grazing. I started to see some really positive results in soil quality. My soil was holding more moisture, so I needed to irrigate less. I used to spend $400,000 a year on fertilizer, and those numbers were before this recent rise in fertilizer prices. Now I don’t apply any. Don’t miss that!—I haven’t applied any fertilizer since 2019, and my soil keeps getting more productive. I still have a lot to figure out, especially how and when to move cattle to where they need to be at any given time. But every year I learn a bit more. My input costs are way down and other than some minimal herbicide applications, I could almost qualify as organic. With this year’s drought, limited irrigation, and high fertilizer prices, I am really glad I made the changes I did. My only regret is not making them sooner. How much better results could I have had this year if I had started earlier?
Cattle as the Cash Crop

Many farms in the Midwest have gravitated towards a corn-soybean rotation, as the profitability of raising small grains like wheat has stagnated in recent years. One of the big drawbacks of a corn-soybean rotation is that soil quality tends to decline, even under no-till farming. The soil often becomes quite hard and compacted because the combined months of active plant growth and root exudation between the two crops is only about seven months out of the 24-month period. Soils devoid of vegetation naturally become compacted due to the simple force of gravity and the compacting action of raindrops, while soil microbes fed by root exudates create aggregation and reverse compaction.

After years of only corn and soybeans, soils often become hard as adobe and this is when many farmers give up on no-till, because they can’t get planting equipment to penetrate the soil. This is not a failure of no-till, it is a consequence of an agronomically unsound rotation. Still, it is difficult to justify including a traditional small grain in the rotation when the cash flow just doesn’t work. However, some farmers have discovered an innovative crop rotation that can create huge soil health benefits in just one calendar year away from corn or soybeans.

I saw this crop rotation in full effect on a visit to South Africa a couple of years ago. Farmers would dedicate a full cropping season to a summer annual grazing mix consisting of sorghum-sudangrass, pearl millet, cowpeas, sunn hemp, sunflowers, and buckwheat. The copious root exudates, combined with high residue production and manure deposition, created an amazing improvement in soil quality in just one season. The following corn or soybean crop had a far better yield than the same crop on neighboring fields in the traditional corn-soybean rotation. The profitability of the rotation simply blew away the traditional rotation, especially after the grazing income was figured in. One farmer I spoke with showed me his Haney soil test results, comparing the systems. The test before the cover crop indicated about 12 lbs/acre of available nitrogen and 9 lbs/acre of available phosphorus. One year later, the test showed 132 lbs/acre of nitrogen and a staggering 90 lbs/acre of phosphorus. This is a testimony to the ability of a diverse summer cover crop mix to nourish soil microbes that are able to convert previously unavailable forms of phosphorus into plant available forms. It is truly amazing what soil microbes can do when given plenty of food, cover, and time. When I spoke about this to farmers in the US, the question they had for me was, “How well would that work around here?” The resounding answer among those who have tried it here was nearly unanimous: even better.

The advantage we have in the Midwest and Great Plains regions of the US for this rotation is that, unlike South Africa, we usually have some winter moisture that makes winter crops feasible in addition to the summer cover crop. Here is what the system could look like:

<table>
<thead>
<tr>
<th>Option 1: Full Season</th>
<th>Option 2: With Wheat Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fall</strong></td>
<td>Harvest corn/beans</td>
</tr>
<tr>
<td><strong>Fall</strong></td>
<td>Harvest corn/beans</td>
</tr>
<tr>
<td><strong>Fall</strong></td>
<td>Plant rye/triticale/vetch/winter peas</td>
</tr>
<tr>
<td><strong>Fall</strong></td>
<td>Plant wheat for grain</td>
</tr>
<tr>
<td><strong>Spring</strong></td>
<td>Graze winter mix</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td>Harvest wheat for grain</td>
</tr>
<tr>
<td><strong>Late Spring</strong></td>
<td>Plant warm season mix of sorghum, millet, cowpeas, sunn hemp, buckwheat, sunflowers, etc.</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td>Plant warm season mix of sorghum, millet, cowpeas, sunn hemp, buckwheat, sunflowers, etc.</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td>Rotational graze summer mix</td>
</tr>
<tr>
<td><strong>Summer</strong></td>
<td>Graze summer mix</td>
</tr>
<tr>
<td><strong>Fall</strong></td>
<td>Plant rye/triticale/vetch/winter peas</td>
</tr>
<tr>
<td><strong>Spring</strong></td>
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<tr>
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<td>Plant corn/beans</td>
</tr>
</tbody>
</table>

But wait, there’s more! You can also derive grazing income from the winter grazing crops. Grazing income from winter cover crops will vary widely with moisture and winter temperature, but here in the middle of the Plains it is common for a winter grazing crop to support 1000 lbs of live weight per acre for a month or so (more as you go south, less as you go north). If this was two 500 lb calves per acre gaining two pounds per day, that could add another 240 lbs of gain per acre, or at the same assumption of $80 per pound of gain, $192 more per acre. This can add greatly to the total amount of grazing income. Add it all up, and grazing income can compete with grain crops if both are managed well.

Ultimately, while the grazing income is quite nice, what really excites me about this rotation is the typical eye-popping increase in the yields of the following corn and soybean crops (I have heard as much as 50% increases, but 10-20% is more common); this indicates to me that there is something very positive happening belowground when diverse, productive cover crops are properly grazed in livestock in a rotation with cash crops.

An alternative option that can work almost as well is to do a similar rotation using wheat as a cash crop instead of the first rye-based grazing crop.

Cash crops. An alternative option that can work almost as well is to do a similar rotation using wheat as a cash crop instead of the first rye-based grazing crop.

How much grazing? This will vary widely among locations depending on soil, weather, and management, but a well-planned and managed summer grazing crop can produce forage to support 200 grazing days per acre for a 1000 lb animal with excellent animal gains (2.5-3.5 ADG is common). To put this in perspective, an acre could carry 400 head of calves weighing 500 pounds apiece, with each gaining over two pounds per day. That is potentially 800 pounds of beef per acre, and when a pound of gain generates about $0.80 of income, that is the same gross income (800 x $0.80 = $640) as 160 bushel corn at $4 a bushel, with far less input costs than a corn crop.

In Managing Pasture, author Dale Strickler guides farmers and ranchers through the practical and ideological considerations behind caring for the land as a key part of running a successful grass-based operation, from the profitability of replacing expensive grain feed with nutrient-rich native grasses to the benefits of ecological-minded land management. In-depth examinations of the biology and benefits of grazing plants and different grazing strategies accompany detailed plans for paddock and fencing set-ups, livestock watering, and effective methods for dealing with common pasture problems throughout the seasons, from mud to drought.

For readers invested in pasture improvement strategies that offer environmental benefits beyond better meat and dairy, including carbon sequestration, erosion prevention, increased pollinator resources and wildlife habitat, and improved water quality, Managing Pasture is an indispensable guide to creating and caring for the grassland that feeds animals and future generations. To order your own copy, visit www.dalestrickler.com.
Making Cattle Profitable: Year-Round Grazing

In the Beef Science class I took in college, the instructor put a “break-even” number up on the board, totaling all the various costs of raising a beef calf to weaning. Feed cost (80% of total) was at the top of the list, and the vast majority of the cost revolved around providing hay or silage for winter feed, which are expensive because they require mechanical harvesting. That was true in the 1980s, and it is even more costly now. Mechanical harvest requires machinery and fuel, and we all know what has happened to those prices recently. We often do what we do out of habit, rather than making conscious decisions. In 1973, fat cattle were selling for $3.50 a pound, and you could buy a newly invented big round hay bale for $3000, so 6000 lbs of steers would buy a new baler. Today, fat calves are bringing $1.25 a pound, but a new baler costs $55,000, so now it takes 44,000 lbs of cattle to buy a new baler—seven times as much as in 1973. The economics of making hay have gotten progressively worse and worse, but just as a frog in a pan of water on a stove that is gradually brought to a boil won’t jump out, we keep right on making hay year after year, even when the economics no longer make sense.

Of course, animals still need fed in winter. But it doesn’t necessarily require feeding hay or silage. Here are some ideas on how to eliminate the need for hay or silage from your livestock operation.

More Acres
Add grazing acres during the winter by using cover crops on cropland. Forage growth requires sunlight and favorable temperatures, which are most abundant in the late spring and early summer. Traditionally, we started feeding hay when the pasture forage ran out. But in its area of adoption, tall fescue is the absolute best stocked forage, particularly novel endophage varieties that do not produce the toxins found in the widespread Kentucky 31 tall fescue. The quality of tall fescue can be quite good even in midwinter, but fescue is a perennial and many people would prefer a stockpiled forage that can be grown within a crop rotation. (Though the profitability of a good stand of perennials can compete with grain crops; see page 23.)

One such option is a non-grain producing forage sorghum, which has a waxy coating on the leaves that make it resistant to winter weathering, and can produce very high yields. Unless the goal is to actually fatten animals on grain, a grain producing hybrid is undesirable because ruminant animals that consume too much grain often develop acidosis. There are three broad traits in sorghum that prevent grain production. The first is photoperiod sensitivity, in which the plant does not begin to flower until day length drops below a certain length, usually 12 hours and 20 minutes, in which case there is not sufficient time before frost for grain to develop. Photoperiod sensitive plants tend to be very high yielding and drought tolerant, but often get very tall and sometimes lodge, and their quality might not be quite as good as other types of sorghums with better forage traits. A second trait is male sterility, in which case the pollen is incapable of fertilizing the female parts of the plant. (Though if there are male fertile sorghums—regular seed producing hybrids of sorghum, shattercane or even Johnsongrass—in the field, then male sterile hybrids can produce grain.) Male sterile hybrids usually have excellent palatability, because when there is no developing seed to fill after flowering, the sugars produced by the plant simply accumulate in the stalk, making for a very sweet plant with palatable stalks. The third approach is to simply plant a very long maturity hybrid later in the season, too late for grain to ripen. This is an approach I prefer when double cropping a stockpiled sorghum after wheat harvest. I really like the long maturity, dwarf brown midrib forage sorghum as it stands well, yields great, is inexpensive to plant, and has great forage quality. But if planted too early, it can produce huge amounts of grain and risk acidosis with direct grazing.

Stockpile Forages
One of the most empowering ideas I have ever learned in forage management is that the grazing season is not limited to the growing season. Some forages retain their quality into the winter while others do not. In its area of adoption, tall fescue is the absolute best stocked forage, particularly novel endophage varieties that do not produce the toxins found in the widespread Kentucky 31 tall fescue. The quality of tall fescue can be quite good even in midwinter, but fescue is a perennial and many people would prefer a stockpiled forage that can be grown within a crop rotation. (Though the profitability of a good stand of perennials can compete with grain crops; see page 23.)

One such option is a non-grain producing forage sorghum, which has a waxy coating on the leaves that make it resistant to winter weathering, and can produce very high yields. Unless the goal is to actually fatten animals on grain, a grain producing hybrid is undesirable because ruminant animals that consume too much grain often develop acidosis. There are three broad traits in sorghum that prevent grain production. The first is photoperiod sensitivity, in which the plant does not begin to flower until day length drops below a certain length, usually 12 hours and 20 minutes, in which case there is not sufficient time before frost for grain to develop. Photoperiod

Winter grazing of summer planted warm season mixes can be very successful and save tons of hay. When done properly, the nutritive needs of the cattle will be met through the majority of the late fall and winter. The third approach is to simply plant a very long maturity hybrid later in the season, too late for grain to ripen. This is an approach I prefer when double cropping a stockpiled sorghum after wheat harvest. I really like the long maturity, dwarf brown midrib forage sorghum as it stands well, yields great, is inexpensive to plant, and has great forage quality. But if planted too early, it can produce huge amounts of grain and risk acidosis with direct grazing.

Set Yourself Up for Stockpiling Success
One other concept that I have discovered to be highly useful when it comes to making forage and is one that you already grazed off in the fall. For example, tall fescue is an excellent winter grazing resource, but if animals are simply left on it all summer and fall, there will be nothing left to graze in winter. Providing alternate grazing resources during summer and fall can allow the fescue to be rested in summer (when the forage quality is poor and the endophage toxicity is high) or fall, and be available to use in winter when it is better than just about any other grazing option. In a conversation I had with a farmer last summer at a farm show, he asked for a recommendation for a sudangrass for baling. I told him I favor the sudangrass hybrid for haying, and then asked a few more questions. It turns out he had an adjacent pasture composed of nearly pure tall fescue. I asked him why he didn’t graze the sudangrass in the summer and stockpile the fescue for winter grazing. He looked at me like I had a third eye in the middle of my forehead, and said, “Now, I can use my fescue in summer and I need the sudangrass for hay in the winter.” That, folks, is like using a Ferrari to pull a plow and a tractor to drive to town. If he had used the sudangrass for pasture for the months of July, August, and September, he could have put likely an extra 100 lbs of weight on his calves and improved his brood cow percentage, because sudangrass is a far superior summer forage than fescue. He also would allow his fescue enough growth over those 90 days or so that he could graze far into the winter with some fescue acres, and not have to feed hay. Doesn’t it make sense that three months of rest in the summer could add three more months of grazing at the end of the season? He could also drill rye into the grazed off sudan, and graze that rye in the winter as well for even more hay savings. Best of all, he could skip all the time, expense, and aggravation of making hay out of the sudan. We are talking about the same exact acres of land, but with far better animal performance and far less cost.

Always Have a Plan B
Even with the best-laid plans, it is wise to have some hay on hand, because things never work out exactly like you plan. Hay on hand provides peace of mind. But just like planning on collecting crop insurance is a really bad business plan, a livestock feeding plan with no alternative other than feeding hay for half the year is also a bad business plan. Have hay on hand, but don’t just feed it because you made it and want to justify the effort. Try to have every month covered with a grazing resource, possibly more than one, and keep hay as a last resort. If you have ruminant livestock, there is probably no other practice that will improve your profitability more than reducing the amount of mechanically harvested feed that your animals require.
Everyone Complains About the Weather

We have all heard the old saying that everyone complains about the weather, but no one does anything about it. But the truth is that we have been doing something about the weather for centuries. We’ve been making it worse.

How are we doing this, and how can we change our ways to improve our weather? We are starting to understand how land management affects weather, and a few folks are using this knowledge to do something about it!

Alejandro Carrillo is a regenerative rancher in the harsh, brittle environment of the Mexican Chihuahuan desert. For years his neighbors have claimed that the better grass production on his ranch was because he was just “lucky” and it rained more on his place than theirs. However, it is now becoming increasingly apparent that it does rain more on Alejandro’s ranch. That isn’t just luck, it’s because he manages his land differently than his neighbors, and his grazing management is actually causing an increase in his local rainfall. This localized gain in rainfall is being increasingly verified by local weather experts.

A webinar recently discussed climate trends in Kansas. It appears that the wettest area of Kansas (the southeast) has been getting wetter, gaining about two inches of precipitation over the last few decades. The driest part of Kansas (the southwest) has been getting drier, losing an inch or two of annual precipitation. This isn’t good, and it gets even worse. Statistical analysis indicates that rainfall events are indeed becoming what many of us have suspected: less frequent and more intense. But the bigger questions are why is this happening and what can we do about it?

The first inclination is to blame these changes on climate change, which is being attributed to increased levels of atmospheric carbon dioxide. Is it truly that simple? Are these changes due to the near doubling in atmospheric CO2 that have occurred since the beginning of the Industrial Age? Or is there something else going on? There is increasing evidence that it is indeed much more complicated, and that our land management is a major factor. The dramatic rise in atmospheric CO2 is likely a contributing factor, but it may not be the biggest one. According to internationally recognized climate scientist, Walter Jhne, the biggest driver of climate change may not be CO2 but rather changes in our water cycle. Water has a very high specific heat, which is a measure of its resistance to temperature change. That is why deserts can be blazing hot in the day and quite cold at night, and why the dry centers of continents experience wider swings in temperature than coastal areas.

The evaporation of water from soil and the transpiration of water vapor from plants cool the soil and the surrounding environment. Any management change that results in less water being captured and held will result in localized heating. Bare soil and tillage result in less water infiltration, lower water holding capacity, and no cooling transpiration from vegetation. New extrapolate that local effect over millions of contiguous acres and you get a “heat dome” of rising hot air that tends to move bodies of moisture laden air away from hot, dry areas that desperately need the rain. Growing plants and abundant surface residue keep the soil surface and air above it cool. When we use soil health practices, we can increase rainfall infiltration, hold soil moisture longer, transpire more moisture, and if these practices occur at scale, it will help eliminate the heat domes that contribute to both short and long term drought.

Large areas of bare soil also have other influences on rainfall and climate. For example, when we were taught in school that there was a speck of dust in the center of every raindrop? It’s true that pure water in the form of water vapor will not form a raindrop without condensation nuclei to which the water is magnetically attracted.

But the dust that blows up into the atmosphere from large areas of bare, tilled soil are not very effective condensation nuclei. It takes a huge amount of water vapor to form a rain event when the primary condensation nuclei are soil particles. It takes a long time for enough moisture to accumulate to make it rain (thus rain becomes infrequent) and there is a lot of moisture in the atmosphere when it does rain (thus rain becomes more intense).

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Effective condensation nuclei that are highly attractive to water vapor and promote frequent, gentle rain are all biological in origin. Examples include bacteria (like Pseudomonas syringae) which commonly live on the surface of plant leaves, pollen grains from flowering plants, fungal spores from decaying plant residue, and volatile organic compounds emitted by the leaves of growing plants. When we minimize tillage and keep land surfaces covered with decaying plant residue and green plants (especially flowering plants), we can encourage frequent and gentle rain. While this seems to be a complete revelation to us in agronomy, ski slopes have been using bacteria to help make artificial snow for decades. In the 1970s David Sands, a plant pathologist at the University of Montana, found that fungal spores triggered rain in that location. Dr. Brent Christner of Louisiana State University found similar evidence of bacteria inducing rainfall, which was the subject of an article in the January 2009 issue of National Geographic.

There are also other mechanisms by which land management affects weather. One is called the “green pump” in which trees bring up stored soil moisture and slowly put it into the atmosphere through transpiration, where the moisture condenses into clouds and drops rain again. This phenomenon was first observed on Pacific islands where the trees were removed and then the rainfall stopped occurring inland and was only limited to the coasts.

Another mechanism is called the “short water” cycle, in which local rainfall occurs through the movement of water vapor vertically into the air and it hits a cool layer in the upper atmosphere and falls again as localized thunderstorms (as opposed to the movement of large warm, moisture-laden air masses colliding with large cold air masses to form a front with gentle rain over a large area). When it rains on large areas of bare soil, the moisture evaporates quickly, leading to high chances of another rain. When the soil is covered in vegetation, little moisture is lost to evaporation; instead, it is slowly released through transpiration. Thus, bare soil again contributes to a cycle of long periods with no rain, followed by periods of intense rain while covered soil contributes to more frequent and gentle rains that are well distributed over time.

When large blocks of land are managed with regenerative practices that maintain soil cover and have growing plants, such as no-till, cover crops, and managed grazing, the region likely will experience an increase in the frequency of local rainfall. Although it is hard to conduct controlled research on this topic, both scientists and producers believe they are witnessing this phenomenon.

Ranchers in arid areas, like Alejandro Carrillo, have seen an increase in local rainfall following their adoption of adaptive multi-paddock grazing with long rests. This grazing method causes an increase in grass production, which improves the amount of much available, which in turn increases the infiltration of rainfall and slows the evaporation of soil moisture. There is more soil moisture stored with each rain, and this “primes” the system. The taller grass remnants left after each managed grazing period and the long rest periods between grazing increase the amount of photosynthesis, and increases root exudes that build soil organic matter. This in turn allows the soil to hold more moisture, rather than letting it percolate away. The regrowth of the plants allow a slow transpiration of this stored soil moisture, contributing to increased local rainfall events. Regenerative practices like no-till, cover crops, and especially improved grazing management is how we stop and reverse desertification. Knowing this gives you the ability to not merely complain about the weather—now you can do something about it! For more information on these topics, check out these YouTube videos: Grazing the Desert, Alejandro Carrillo, by Understanding Ag Walter Jhne – Understanding the Water Cycle by Biominvent Food Association How to green the world’s deserts and reverse climate change | Allan Savory by TED
The Plant-Microbial Communication Network

Most humans feel adept and evolved in their ability to communicate their needs, wants, and desires. However, our communication skills pale in comparison to plants and the microbiology in the rhizosphere. Imagine being a plant, rooted into the earth and unable to flee from a predator or undesirable situation. Imagine being a tiny microbe, down in the soil, away from light, in very hostile environments. Both plants and microbes have incredible sensory and communication systems that help them determine and distinguish between food, friend, and foe. This article will highlight some of the systems and will hopefully whet your appetite to take a deeper dive into the subject!

If you zoom into a plant cell, you will see that every single cell wall has hundreds of thousands of receptors ready to bind to signaling molecules. These receptors function like keys, turning gene expression on or off, which affect how a cell functions without allowing molecules to enter the cell.

The number and nature of the understandings around plant and biological “in-fochemicals” is a rapidly growing field of study. Plant root exudates are a conductor for this underground microbial chatter, sending out packages containing amino acids, sugars, hormones, and organic acids, altering microbial biomass and species diversity. These exudates also include “communication chemicals”—secondary metabolites such as fatty acids, steroids, glucosinolates, enzymes, flavonoids, lignins, and more. These carbon-based exudates provide diverse benefits and act as payments to stimulate the microbes providing beneficial services. They also act as communication signals to suppress and defend against pathogens and pests as well as playing a key role in aggregate stability and carbon and nitrogen dynamics.

One group of molecules produced by plants and microbes are called volatile organic compounds (VOCs). These VOCs can easily move through gas- and water-filled pores. VOCs provide multiple services to plants, including triggering plant immunity, promoting plant growth, enhancing antimicrobials, and increasing attractiveness to beneficial insects. Some microbes produce a huge variety of communication VOCs (over 800 have been identified thus far). Many of the stronger odors you’ll be familiar with are actually microbial VOCs: feces (indole), urine (ammonia), vomit (butyric), rotting cabbage/fatty smells (methyl mercaptan), rotten eggs (hydrogen sulfide gas) and rotten potatoes (dimethyl disulfide). The distinctive “funky” aroma of the mycorrhizal truffle is in part due to dimethyl disulfide and from a molecule called androsterone, a hormone produced by male pigs. This in part explains why pigs can make such good truffle hunters. The fungus sends out this signaling scent to pigs, and to us, to find the truffle when it is mature. This aids in completing its reproductive cycle, which is limited by sporulating underground. These spores pass through the digestive tract, remaining viable when anything, or anyone, poops in the woods. Geosmin is what gives beer its taste and what creates the smell after a shower of rain meets the road on a hot summer’s day. The smell of geosmin released by Streptomyces has been found to attract collembola (springtails), which then aid in the dispersal of its spores. We can smell geosmin at five parts per trillion, and a shark can smell blood at one part per million. That means human noses are 200,000 times more sensitive to geosmin than a shark is to blood.

Microbes are also streaming chemical and electrical signals to communicate with each other and with their vital support system, the plants. Testate amoebae, the ones who fashion themselves in hardened shells for protection, have been observed hunting together as a pack, to track down and attack bacteria-feeding nematodes. Their hunting behaviors are determined by these signaling molecules. Even though leaf surfaces are vulnerable to frequent and severe changes in temperature, radiation, and humidity, there are a large variety of microorganisms which thrive on them. Bacteria living on aerial leaf surfaces totally differ from bacteria found in other habitats, including surrounding soil, implying that they have evolved and developed special adaptations to take advantage of leaf surfaces. The ability to tolerate challenging environments comes through phytophagy (short-term changes in an individual) as well as adaptation (epigenetics). Epigenetic changes passed down through generations of plants, have a role in memory and priming plant defenses to potential pests and diseases. For instance, a study of plants infected by root nematodes, showed an increase in root defense genes in multiple generations. Epigenetics also prepare future generations for extremes of water, nutrient and heat dynamics. It makes me wonder how we might possibly be undermining plant “learning” processes with modern breeding programs, pesticides, and fungicides?

Quorum Sensing

Using chemical autoinducers as their “words”, microbes can communicate in multiple languages, both within and between species. In a process called quorum sensing (QS), cell receptors can synchronize their behaviors when sensing specific chemical molecules. Based on the “message” they get, they can either compete or collaborate with other species. These messenger molecules include AHLs (acyl homoserine lactones) and DSF (diffusible signaling factor) to trigger activities at parts per trillion.

The process of QS was first discovered in bio-luminescent bacteria in the 1960s. With growing concerns around the exploitation of antibiotics, medical research in the ’90s identified QS’s role in streptococcus virulence. When populations are small, microorganisms are unable to express certain genes, as full gene expression requires a community. When numbers increase, autoinducer signals reach a threshold, and the full gamut of gene expression can now switch on and you could end up with a sore throat or a nasty itch. In another process termed “quorum quenching”, signals are used to inhibit the invasiveness of the organism. Communication via quorum sensing is now considered the norm in the bacterial world. Plants also release molecules to suppress QS-specific pathways, including binding molecules, such as terpenes, phenylpropanoids, flavonoid quercetin, fur-containing compounds, or quorum quenching molecules; coumarin, vanillic acid, and curcumin.

Microscopic view of testate amoeba (Centropyxis aculeata) shell.
Another example of communication complexity comes from the 1960s when a former CIA polygraph expert hooked a plant up to his machine and discovered that not only did the plant react to being burned, but it also reacted with a surge of electrical activity whenever he entered the room. A recent study on the “ultrasonic screams” of damaged plants suggests that if farmers can tune equipment to “listen” to plant distress signals, that pesticides and fungicides could be used more precisely with less guess work. Of course, the premise that plants have consciousness has long been hugely controversial, with scientists arguing that without a brain, plants cannot “feel pain.” Plants, however, are very sensitive to their environment, avoiding touch (like crown shyness in trees), responding to light (phototropism), or responding to tactile stimuli (think vines wrapping around a trellis). This touch may be as light as a small raindrop, or the tread of an ant’s toe.1

Plant signals may also provide indirect forms of defense to attract beneficial microbes or predatory/parasitic in- sects, such as herbivore-induced plant volatiles (HIPV’s). Maize plants release a sesquiterpene signal into the root zone when infested by *Fusarium* sp., or when attacked by root-feeding beetle larvae, resulting in the enhanced attraction of beneficial nematodes.2 Plants can sense benefi- cial predators such as ants, and as a reward for the pro- tection predators and parasites provide, plants increase the quality and volume of extrafloral nectar (EPF). Small sig- naling molecules and proteins exuded by microorganisms can support the plant in improving overall health and re- sistance to pathogens and viruses.3 The amino acid glutamic- acid, which acts as a neurotransmitter in humans, triggers rapid long-distance signaling using calcium throughout the plant. A study using mustard plants that were genetically modified to fluoresce when cut or munched on by caterpillars showed that plants were able to send internal signals via a “nerve like” process to send a warning of im- minent danger. Plants also have their own kind of “intra-organismal” system on Science Magazine’s YouTube channel.4

Two of the most extensively studied mechanisms for plant induced defenses are systemic acquired resistance (SAR) and induced systemic resistance (ISR). After a plant is exposed to microbial elicitors or chemical stimuli, such as chitosan or salicylic acid, the SAR response is activated throughout the plant. Using different mechanisms, ISR relies on signal pathways activated by the hormones jasmonate and ethylene and occurs in plants activated by an infection. During ISR, plants respond with a signaling cascade that leads to a broad and long-lasting resistance that is effective against fungi, bacteria, and viruses. Protection by ISR has been reported against a wide range of pathogens, including systemic viruses such as cucumber mosaic virus, root-knot nematodes, leaf-spotting fungal and bacterial pathogens, scirerotina, crown-rot, stem- blight fungus, damping-off, powdery mildew, Botrytis, take-all, and fungal or bacterial blight diseases. As an added bonus, in most cases, the microbes that stimulate ISR also promote plant growth.

What is fascinating is without their beneficial microbial partners, these pathways are inhibited (how amazing is that)! These defense responses are triggered by a range of beneficial microbes including *Pseudomonas* spp., *Trich- oderma* spp., *Myccorrhizae* spp., yeasts, *Rhizobacteria*, *Bacillus* spp., and other gram-negative bacteria. These microbes trigger plant gene expression, which results in increased growth, immunity, and resistance to stress. Pathogen resistance from *Trichoderma* interactions take multiple forms through the action of its diverse exudates which contain volatile organic compounds, cell wall degrading enzymes, reactive oxygen species, and antimicrobial secondary metabolites. By forming these interactions, *Trichoderma* increases plant fitness and tolerance against biotic stress either by priming plant defenses, increasing plant growth, or releasing pathogen pressure leading to the enhanced growth response.

**Induced Systemic Response.**

On the side, the plant is in- fected with botrytis, a fungal disease, without the presence of beneficial organisms *Trichoder- ma*. On the right, ISR from roots colonized by the fungus *Trich- oderma* is primed for response with plant defense hormones jasmonic acid (JA), salicylic acid (SA), and abiotic acid (ABA).5 Image based on Martínez-Medina, et al (2013).

**What Reduces Plant and Microbial Signals?**

The ability for plants to communicate with microbiology is influenced by:

- Nutrition
- Plant diversity
- Photosynthetic metabolites
- Plant stress and disturbance
- Plant breeding
- Growth phase

Different species and plants during different growth stages, release a diverse cocktail of root metabolites. Plant stress has a huge influence on a plant's ability to share resources. Annuals, perennials, and early succes- sion plants send different signals depending on their circumstances. Each stage of a plant’s cycle such as ac- tively growing, under attack, or ending their life cycle, will trigger a different set of signals to the plant’s envi- ronment. Sadly, plant breeding done in altered or ster- tile environments has altered specific communications from plant roots, so that some cultivars, such as some wheat varieties, no longer signal to beneficial protists for nutrient cycling or bacterial control, or no longer initiate symbioses with mycorrhiza.

Insecticides, fungicides, and herbicides can negatively impact (directly or indirectly) photosynthesis and the subsequent root exudates necessary for quorum signal- ing. Enzymes and signals involved in nitrogen fixation and transforming free amino acids into complete pro- teins are compromised by these chemicals.6

Through biopriming seeds with beneficial microbes (compost extracts) or carbon-based foods (humics, sea- weeds, etc.), we can restore microbial communities and enhance plant fitness. Multi-species cover crops, inter- planting and diverse rotational crops are key tools in re- generating microbial biomass and diversity.

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**Footnotes**


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**For the Love of Soil! Strategies to Regenerate Our Food Production Systems** translates the often complex and technical lower-levels of soil into more digestible terms through case studies from regenerative farmers, growers, and ranchers in Australasia and North America which present a compelling testament to the global, rapidly growing soil health movement.

Along with sharing key soil health principles and restoraton tools, *For the Love of Soil! Strategies to Regenerate Our Food Production Systems* showcases examples of the tools and methodologies of soil health movement and provides practical guides and resources to create healthy, regenerative agricultural systems. The first 5 days covers hands-on learning and classroom time. The following 16 weeks includes a 2-3 hour webinar, online learning, and coaching support. At the end of the program there is a 3-day session back in the field to bring all of the learning together. At the completion of this training, attendees will have the business skills, tools and resources to help restore and transform the often complex and technical know-how of soil into more digestible terms through case studies from regenerative farmers, growers, and ranchers in Australasia and North America which present a compelling testament to the global, rapidly growing soil health movement.

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What Is in a Seed? And Why Is It Important?

Isn’t it amazing how a seed can transform into a plant with roots and leaves and flowers and fruits—or maybe grain—or perhaps even grow into a huge tree that lives for hundreds of years?

This is possible because the seed’s DNA contains a genetic code, encrypted with instructions for the hundreds of processes that enable a germinating seed to grow into a mature plant and eventually produce seed for the next generation. The genetic blueprint is quite specific. We know that a tomato seed will grow into a tomato plant and a corn seed will grow into a corn plant, because that’s what it is programmed to do.

In addition to DNA, most seeds also contain energy reserves in the form of starches, oils, and proteins. In cereals and oilseeds the energy is stored in the endosperm whereas in some dicots such as beans it is stored in the fleshy cotyledons. These energy reserves support the seedling until it can photosynthesize and feed itself. One tiny drop of fluid from the rumen of a sheep or cow, for example, contains 10,000 times more microbes than there are humans on the planet.

The microbes in seeds are located inside the seed coat and surrounding the embryo. As the seed begins to germinate they move into the radicle (primary root). This represents the first stage of the formation of the plant’s rhizosphere microbiome.

Numerous studies have shown the microbial composition of the rhizosphere (the area surrounding plant roots) differs markedly from the bulk soil (the soil not in contact with plant roots). Some of the microbes found in the rhizosphere are not found in bulk soil and vice versa. This finding has led scientists to believe that the rhizosphere microbial community has been selected for and actively promoted by the plant, by means of root exudates that signal to—and support—some microbes and not others.

Recent research has shown that assumption to be only partly correct. In the early seedling stage, the majority of microbes inhabiting the rhizosphere originate from the seed, which is why they differ from the microbes in bulk soil. The relative contribution of seed and soil sourced microbes is influenced by the soil environment. In biologically active soils, such as found in tropical rainforests, around 55% of microbes in the juvenile rhizosphere are seed-derived, whereas in soils of low biological activity, up to 90% of the microbes in the juvenile rhizosphere originate from the seed.

Once the primary root has emerged the first shoots appear. These too are colonized by microbes originating from the seed. As the plant grows the core microbiome moves into stems, leaves, flowers, fruits and eventually back into the seeds for the next generation.

Indeed, we now know that a seed has a core microbiome containing in excess of 1000 species of bacteria, archaea, fungi, and, even some protists. Which is not totally surprising, given that all living things are colonized by microbes. It would be more of a revelation to find seeds were sterile. Microbes are extremely small and incredibly abundant. One tiny drop of fluid from the rumen of a sheep or cow, for example, contains 10,000 times more microbes than there are humans on the planet.

The microbes in seeds are located inside the seed coat and surrounding the embryo. As the seed begins to germinate they move into the radicle (primary root). This represents the first stage of the formation of the plant’s rhizosphere microbiome.

Microcrhizal fungi form beneficial symbiotic relationships with the vast majority of land plants and have been the only microbes to form important relationships with plants in the legume family, such as peas and beans. Advances in technology have enabled us to in-
What the Heck Is HyprGrow?

HyprGrow is a liquid biological amendment (LBA) made by Elevate Ag. It is applied at a rate of 1.5 gallons per acre as either an in-furrow product or as a foiliar. Since Green Cover is part owner of Elevate Ag, we wanted to answer some of the questions that people commonly ask about HyprGrow and other LBAs.

Q: Isn’t this just another “snake oil”?

A: Well, if it is, it must be from some pretty high-quality snakes! While it doesn’t actually contain oil from snakes, it does have several other plant- and animal-derived ingredients, all scientifically documented to have plant growth and health benefits, and the field results have been quite favorable.

Q: What is in HyprGrow?

A: Compost extract, chitosan, micronized kelp, molasses, humates and humic acid, worm castings, and yucca extract. Below is an explanation of what each ingredient does. For a more detailed version of this article, including references and scientific sources, visit www.greencover-seed.com and search for HyprGrow.

Compost extract is made from leaching compost through a sieve to create a liquid rich in microbes and microbial byproducts. The specific organisms in the extract will depend on the raw materials and the composting process used. Composts which are turned frequently and oxygenated will be full of aerobic bacteria, which provide a certain range of benefits. Composts made in an anaerobic process similar to silage (like Bokashi composting) will produce a compost very high in lactic acid, providing an array of benefits different from the anaerobic process, and is particularly helpful in stimulating seed germination. A compost made by the Johnson-Su process will be very high in fungal spores, which is key to creating a beneficial soil structure. Compost extract contains live microbes as well as microbial metabolites, which can have numerous positive effects on plant growth, including protection from pathogenic fungi. Most microbes produce chemicals defenses against other microbes, and those chemicals will still be present in a compost extract long after the microbes that produced them have died. This explains the protection against pathogenic fungi achieved from foliar applications of HyprGrow.

Chitosan is an enzymatically digested chitin derived from crab and shrimp shells. Chitin also makes up the cell walls of insects and fungi. Chitosan applied either on seed or as a foliar elicits an immune response in plants, triggering production of chemicals (chitinase, jasmonic acid, and salicylic acid) that fight off attacks from both insects and fungi. Chitinase is an enzyme that the plant produces that simply eats fungal tissue away. Chitosan been shown to prevent fungal diseases of plants, including Botrytis mold of grapes and strawberries. Chitosan has also been shown to improve heat tolerance and drought tolerance in crops.

Kelp (Ascophyllum nodosum) is a seaweed that contains over 70 trace minerals as well as vitamins, amino acids, and the plant sugar manitol which stimulates microbial growth. But most importantly, kelp contains phytohormones that increase plant growth, including gibberellins, auxins, and cytokinins.

Molasses contains sugars that nourish microbes, as well as many important trace minerals. The sticky nature of molasses also gives HyprGrow its ability to adhere to leaf surfaces as a foliar. Molasses has been used to promote plant growth for more than a century.

Worm castings are the feces of earthworms (also referred to as vermicompost) which are proven as a fertilizer amendment, being rich in both plant nutrients and microbial activity. As vermicomposting has become more commonplace, more and more people are realizing the value of worm castings for increasing seed germination, plant growth, and food quality.

Yucca extract is a natural surfactant, active even at very low concentrations. It increases water infiltration when applied to the soil and acts to lower surface tension of water when applied as a foliar, which prevents droplets from running off the leaf surface. Yucca extract is a known microbial stimulant, due to its content of steroidal saponins, plus resveratrol, larinol, and yuccaols. Yucca extract also offers protection against seed pathogens. Humates are ancient decayed plants that have not completely formed into coal. They behave similarly to humus in the soil in that they hold water and sequester mineral nutrients in a form that is more available to plants, thus enabling top yields with less fertilizer, particularly with phosphorus fertilizer which is notoriously unavailable in soil. Humic acid, which is made from humates, is a natural soil conditioner that acts as an organic chelator (a binding agent) and microbial stimulator. It has a unique carbon matrix which includes a high concentration of trace minerals and organic acids. Humic acid enhances the plant’s ability to take in essential nutrients and improves soil structure. Think of it as the pantry to the soil kitchen.

Q: What kind of results have you seen from HyprGrow?

A: There are no magic yield enhancers. As with any product used to enhance yield, it will give a yield response if it provides a boost to an otherwise limiting growth factor, or if it reduces yield losses from disease or insects. Any one who pitches a product saying “this product will give you an extra 10 bushels an acre every time you use it” is lying—there is no such product. Look at two of the most highly regarded agronomic inputs: nitrogen fertilizer and irrigation. Nitrogen fertilizer is of no benefit to a corn crop if the corn is planted into a freshly terminated alfalfa stand where there is abundant available nitrogen, because nitrogen fertility is not limiting. Irrigation is of no benefit in the Amazon rainforest where it rains over 100 inches a year, and moisture is not limiting. Yet we never question the value of nitrogen fertilizer or irrigation as yield enhancers, because we understand the conditions in which they increase yield and apply those inputs to those conditions. Likewise, HyprGrow will increase yield under conditions in which it can supply limiting growth factors. HyprGrow as a soil application can enhance soil microbial activity which can make some plant nutrients more available, provide phytohormones that increase root elongation and reduce root-attacking plant diseases, so plants are better able to take up both water and nutrients. If either water or nutrients are lacking during the growing season, then HyprGrow applied in-furrow can provide a definite help. As a foliar, HyprGrow can supply a limited quantity of foliar absorbed nutrients, as well as provide protection from many foliar diseases, including from bacterial diseases like Goss’s wilt for which fungicides are completely ineffective. If foliar plant diseases or mineral nutrient deficiencies are limiting yield, then there’s a good chance HyprGrow applied as a foliar can help increase yield.

We have had some customers see some excellent results, and a few have seen very limited results, but in almost all cases the application of HyprGrow has been quite economical. In-furrow applications seem to provide excellent benefit in dry regions, while foliar seems most effective in areas with foliar diseases like leaf rust on wheat or gray leaf spot on corn.

Here is what others have said:

“I used HyprGrow on the seed for malting barley. The crop had a more even emergence and a different, darker color than usual and was a little earlier in maturity, with about 5 bushel better yield than normal. Our protein was also a percentage point higher than usual.”

-Todd Olander, Colorado

“We had an increase of 2.5 bales/acre using HyprGrow in the furrow at planting, beating yearly and county averages. True BOL of $120/acre. We also had 2% increased protein on 2 foliar applications to our wheat field (15 gal/acre).”

-Jimmy Emmons, Oklahoma

Q: What other products does Elevate Ag offer?

HyprGerm is used as a biological seed treatment at a rate of 6 oz/100 lbs of seed and contains high concentrations of humic acid, kelp, chitosan, and worm castings. Any cover crop seed mix from Green Cover can easily have HyprGerm applied to it. SoliStim contains HyprGrow plus fulvic acid and is applied at one gallon per acre. It’s designed to make herbicides, fertilizers, insecticides, and other nutritional sprays more effective. Mixing with other inputs allows you to co-apply and reduce application. Anchor-N contains humic acid, molasses, and molibdenum. It is designed to increase the efficiency of nitrogen applications.
Soil fertility and conservation have been central areas of focus for farmers for over a century, from the first implementation of the tractor to the advancement in cropping systems and fertility management. The invention of the Haber-Bosch process utilized molecular nitrogen (N₂) and methane (CH₄) gas to synthesize the making of ammonia (NH₃). This later led to the Ostwald process in making nitric acid, leading to the development of ammonium nitrate. In 1927, Erling Johnson invented a method to produce nitrophosphate, and the commercial fertilizer industry was born.

These two newly developed industrial fertilizer products, along with widespread improvements and availability of tractors and other equipment, allowed operators to farm more acres with less labor. This union was the beginning of the agrochemical industry. The industrialization of farming became the accepted method of producing the world’s demand for food, fuel, fiber, and feed. As technology evolved, an increasing need to improve numerous areas in the crop production process followed. These improvements centered on soil conservation practices, seed genetics, soil fertility management, and plant protection.

Soil fertility management emphasized the roles plant nutrients play and how they can be precisely measured. In the 1940s, soil sampling became the method that was introduced to better understand the chemistry of the soil. Laboratory methods used acid extractions to give measurable outcomes that a fertilizer retailer could use to offer fertilizer management recommendations to farmers. Although great strides were made in fertilizer management, soil health was overlooked. The implementation of “precision farming” introduced substantial improvements in soil testing by better understanding the movement of nutrients is processed through biological interactions and interrelationships to move plant nutrients from generation to generation and season to season. Understanding the biological interaction between the plant and the soil is key to improving nutritional efficiencies and soil health.

The debate surrounding how one measures available nutrients within the soil system led to the development of various soil extracts used for identifying soil fertility restrictions and fertilizer response curves in support of better crop production. This process, however, relies almost entirely on inorganic chemistry, both in the extractions themselves and in what we measure for nutrients in the lab. Furthermore, the models were developed on relatively degraded and biologically dead soil systems. Recently, we have seen the introduction of soil tests with greater emphasis on the organic pools of plant nutrients like N and P along with other biological indicators beyond soil organic C and N. One such test is the Haney Test (formerly USDA-ARS, Temple, TX), known as the Haney Test. The Haney Test employs a multifaceted approach to measure various aspects of a living soil system. First, the test uses organic chemistry designed to mimic natural soil solution to extract commonly measured nutrients such as N, P, K, etc. Second, the test includes a measure of soil respiration as an indicator of microbial biomass and potential activity as it relates to nutrient cycling. The third part of the test involves application of the water extraction of organic soil pools of organic carbon (food) and nitrogen (protein) available to the microbes to drive their growth and function. Collectively, all three of these independent processes come together for the past two years to analyze the same soils using both the Haney and BeCrop soil testing methods. Preliminary results from several hundred samples indicate a very distinct relationship between a soil’s current health and fertility status measured on the Haney Test and the indication of open or closed nutrient pathways determined with BeCrop. More importantly, nutrient accessibility can now be seen by observing biological inverse relationships with regard to inorganic nutrient availability, microbial mobilization, and transport to the crop. Based on this vital connection to build a deeper understanding of nutrient management under regeneratively managed farming systems, Regen Ag Lab and Biome Makers have recently come to a partnership under a new licensing agreement.

BeCrop is a proprietary technology developed by Biome Makers that integrates genomic and metagenomic analyzes of the microbial biomarkers providing a meaningful explanation of soil function in agriculture. This test gives microbial analysis and customized interpretation of the soil microbiome based on its biodiversity, vulnerability, and nutrition pathways.

Under this new licensing agreement, Regen Ag Lab will begin performing the BeCrop soil testing at their Nebraska facility in 2022 under the guidance and expertise of the Biome Makers team. Data from the BeCrop analysis will still be uploaded to the current sample portal developed by Biome Makers. In addition, in any sample where the Haney test is performed, these results will be made available directly to the producer as a stand-alone report, but they will also be integrated directly into the BeCrop report provided by Biome Makers as part of the partnership. Lance Gunderson, president of Regen Ag Lab, says, “We are excited about the opportunity this agreement presents to producers striving to gain a better understanding of their soil health journey and refining their nutrient management strategies in the midst of drastically increasing costs of production.

BeCrop report provided by Biome Makers as part of the partnership will still be uploaded to the current sample portal developed by Biome Makers. In any sample where the Haney test is performed, these results will be made available directly to the producer as a stand-alone report, but they will also be integrated directly into the BeCrop report provided by Biome Makers as part of the partnership. Lance Gunderson, president of Regen Ag Lab, says, “We are excited about the opportunity this agreement presents to producers striving to gain a better understanding of their soil health journey and refining their nutrient management strategies in the midst of drastically increasing costs of production.

In the midst of the current agricultural paradigm shift, regenerative practices like cover cropping show a direct link to soil regeneration and fertility, providing producers with a glimpse into the complex natural intelligence of nutrient cycling and uptake in these systems. Soil testing shows how the soil’s community of microbes can impact yield, product quality, and crop longevity. Functional soil analysis assessments empower growers to make informed, science-based decisions to refine fertilization protocols, improve productivity, monitor soil recovery, and prevent pathogenic outbreaks. Now, farmers can measure soil bioactivity and turn low-yield fields into reliable producers through in-depth biological insights.
Regenerative Wildlife Management

The principles of soil health are not only true for cropland and rangeland, but also have positive benefits for wildlife. In order to build wildlife health and populations, we first have to build the soil in order to grow better and more nutritious forages. Wildlife in general and deer specifically thrive on diversity, and will do an amazing job of balancing their diets when given the opportunity to browse an extensive assortment of legumes, grasses, and forbs. Unfortunately, the majority of wildlife food plots consist of monoculture stands of a single cereal species or clover. Most food plots have traditionally relied on disking, fertilizing, and herbicide use, like much of modern industrial agriculture. But just like the soil health movement that we see in regenerative agriculture, a similar movement is happening in the food plot world as well.

Grant Woods has been a leader in this regenerative wildlife movement in his rocky Ozark Mountain “proving grounds” and he has shown that soil can be built by applying the principles of soil health. By keeping the soil covered, keeping living roots in the soil, maximizing diversity, and minimizing disturbance, Grant has transformed degraded, rocky soils with almost no organic matter to rich, productive soils with 5-6% organic matter levels. How did he do this? Here is what he has to say:

The bounty and the beauty of the Summer Release mix is a glimpse of the Creator’s goodness to us. Green plants build black soil, and a diversity of plants build it even faster!

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In 2021, Green Cover and Grant Woods and his Growing Deer team decided to partner to assist wildlife habitat managers grow bigger deer while improving their soils. We are working together to share information, techniques, and high-quality seed blends that will improve the soil’s productivity while attracting deer and providing a greater quantity of quality nutrition to wildlife.

The Release system is based on both biological and agronomic principles and uses the right combination of cover crop plant species and the proper biological organisms to “release” the mineral nutrients from the soil and to capture the carbon and nitrogen from the atmosphere. This combination of plants and biology will build soil faster and grow deer bigger! The keystone food plot blends in the system are the Summer Release (12-way blend of warm season species) and the Fall Release (13-way blend of cool season species). When used and managed properly, these food plot blends will suppress weeds, sequester carbon, fix nitrogen, cycle other minerals, and provide a very balanced diet for deer and other wildlife. For more information visit: www.greencoverfoodplots.com and www.growingdeer.tv.

The Release process is working for people all across the country. A great example comes from east Texas where Grant Woods helped create a habitat and hunting improvement plan for his client, George. One particular “problem” field was filled with pine trees and very poor sugar sand soil. Food plot establishment on this field had been attempted in previous years but nothing ever took, and there had been no significant forage produced for deer. When Grant was evaluating the property, he told George, “The Release process is the perfect solution to increase the quality and quantity of forage produced and give you better habitat and hunting!”

George was skeptical at first but eventually trusted Grant’s opinions and experience. He took his first big step and purchased a no-till drill. George remembers, “Well, like I said, I was not a believer in this system. I did not want to get rid of my disk or my bush hog or my drag. I wanted to broadcast seed like I had always done, but this Release process is amazing, really and truly. The no-till drill has allowed me to do it much quicker.” The Release process saves George time because he needs only one trip across the plots instead of three or four. It reduces his seed costs because he uses 50% less seed when drilling and precisely placing seeds, instead of broadcasting and “feeding part of it to the turkeys, squirrels, crows, or other critters.”

George’s journey started by planting a diverse fall blend of cereal rye, small grains, and some annual clovers. This blend grew well through the fall, winter, and early spring. When soil temperatures were warm enough (60°F), he no-till drilled the Summer Release mix right into that crop. By following the release process and applying the principles of soil health, George has witnessed tremendous improvements in his plots throughout the summer. His fall crop covered, protected, and nurtured both the soil and the biology through the winter, and his Summer Release crop did the same through the hot Texas summer. Better soil has led to increased infiltration and better water holding capacity in the sandy soils, which is critical for success when rainfall is sporadic and unpredictable. Herbicide treatments have also been eliminated as the constant covering of the soil and growing crops have also helped suppress weeds along with providing high quality forage for the wildlife. George notes, “I see fawns bedding down in the forage, older bucks utilizing the plots, and the turkeys absolutely love it!”

George’s fields have tremendous diversity as well as ground cover due to the different crops he has planted in the fall and spring. All the clovers, peas, cereals, and brassicas are working together to help create a biologically rich eco-system. Grant comments “George has made tremendous progress in just one year—there are tons of food and nutrition coming on at different times of the year. It’s just awesome and it will continue to get better as the deer will not only be conditioned to eat in these plots but will learn to live here as well.” This statement is already proving to be true, as George has seen more bucks at his property in the last year than he has ever seen in the past. He didn’t trust that Grant’s plan would work, but after seeing how well his forage has done, he is a believer now. George sums it up by saying, “I’ve never had food plots like this, I have tremendous forage where before plots wouldn’t even grow. It’s been amazing. This Release program really does work and this is the very first time in 35 years that I have had a food plot that I can say I’m extremely proud of.”
Soil Health in Orchards and Vineyards

Cover cropping in orchards and vineyards has grown significantly over the past few years. This is the first time we have written about the topic, and it would be impossible to discuss solutions for orchards and vineyards across the country in one article, so consider this the first of many articles in this realm.

Orchards can include anything from apples to almonds, peaches to pistachios, citrus, cherries, walnuts—the list goes on! While vineyards only produce grapes, there are still countless differences between wine grapes, table grapes, and juice grapes. And with each of the commodities listed above, a huge range of growing regions are represented, from California to New York, Washington to Florida, and many places in between. With such vast diversity of crops and locations within the broad category of “orchards and vineyards”, it may seem silly to group them together at all! Even though many factors differ, we are still talking about growing a cover crop between rows of a perennial crop, and that is a significant common denominator. While we cannot cover solutions for every niche, let’s take time to discuss the questions and considerations we should start thinking about growing a cover crop in this system.

An essential part of the goal setting step is deciding between annual or perennial plants for the cover crop mix. Annuals cost less, grow faster, have more flexibility, and can be planted almost anytime during the growing season. Perennials cost more, have very specific planting time frames, but once established they do not have to be replanted every year. Most of the time, annuals are used in cover cropping scenarios, but in some instances perennials may be preferred. In some regions, if a perennial cool season grass like fescue is already present, diversifying with coverizers such as cover crops, chicory, and plantain may be the simple solution.

**When is the Best Chance to Plant?**

**What are your field operations?** If you don’t already know when your planting window is, think about the field operations required in your orchard or vineyard. If your primary crop requires frequent applications, you may not want a thick cover crop to drive through. If you need a clean floor to harvest off of, in the case of shaking and sweeping for many nut crops, you will want to wait until after harvest to plant something.

**Moisture?** Where moisture is plentiful like the eastern states, there may be the opportunity to plant in just about any month. Elsewhere, like California where rain only comes in the winter and the primary crop only gets drip irrigation, there will not be enough moisture to plant anything during the warmer months.

**Temperature during cover cropped months?** Based on your desired planting season, your species options will quickly sort themselves out as either warm season or cool season. There are a few species that can be used dynamically at different times (buckwheat, rapeseed, saflower, etc.) but typically if you are planting in the fall or winter, you will use cool season species, and if you are planting in late spring or summer, you will use primarily warm season plants.

Within the cool season options, one should also think, “Does my area usually freeze hard?” In many orchard and vineyard regions, it is possible for some light frosts (30-32°F) but it seldom gets colder than that. If that is true in your area, then I would suggest all cool season plants will work. If your area experiences weather routinely dipping below 25°F, be aware that some cool season plants will die. That may be acceptable to you, or perhaps even preferred, but keep that in mind. Plenty of winter hardy plants exist such as hairy vetch, winter peas, winter lentils, various cereals, and perhaps brassicas like rapeseed or kale. (For advice on when each species will or will not cold kill, refer to the species tables on pages 65-73.)

**How Will the Cover Crop Be Terminated?**

If you decide to use annual cover crops, as most do, the last step is deciding how the cover crop will be terminated. If you are in a region like California where the rain has stopped and the row middles are not irrigated, the cover crop will mostly die on its own simply from thirst and heat. Otherwise, spraying or tilling are common termination methods, though we would discourage tillage for terminating covers in most cases.

The wide realm of cover cropping in orchards and vineyards deserves careful consideration of many factors, but it is an exciting frontier. We are grateful to be working with so many innovative producers who are striving to regenerate their farms and lead the industry in this new direction.
I believe in the future of agriculture, with a faith born not of words but of deeds... In living out this opening line from the FFA creed, we reached out to all the FFA Chapters in Nebraska, Kansas, and Oklahoma to share our Soil Health Resource Guide and lesson plans. We also sponsored an essay contest entitled “Why Soil Health Is Important to Me and My Community.” Here are the winning entries from each state. Each winning student was awarded $50 and their chapter was awarded $100, but more importantly, hundreds of students were challenged to think about why soil health is important!

Nebraska Winner: Maggie Clark
Senior, Johnson-Brock High School
Instructor: Ashton Bohling
Soil is the Foundation of all things living, because of this it is important to me and my community. I live in a farming community where almost all jobs are tied in with agriculture. These jobs are available because of good soil health. In the case where our area did not have good soil health my community would be less populated and wouldn’t be able to support the local businesses. Having good soil health allows for a bigger income for farmers which boosts our local economy and helps sustain our community’s livelihood. Practices like no-till, tiling, and cover cropping aid to reduce erosion and help improve soil health and increase the life of the soil. Maintaining good soil health increases yield for farmers and ensures a good harvest for many years to come. Having healthy soil allows for farmers to cut costs on inputs increasing their income. When income is stable for farmers it keeps future generations in the farming industry, which continues to supply jobs for community members. In conclusion, having healthy soil allows for an increase in food production, increases the livelihood of the community, and allows for future generations to flourish. Maintaining soil health is incredibly important to me and my community.

Kansas Winner: Chancey Hauck
Junior, La Crosse High School
Instructor: Ashley Klozenbucher
Soil is important to our world. Both big and small, soil impacts our natural environment. Our world depends on the nutrients and produce that soil provides to our globe. Without true healthy soil, us humans could not be healthy. We need to work with the land and for the land, to provide for many Americans and for future generations. What we do to the soil today such as the care we take and the fertilizers we use will affect many generations to come. We are truly providing for the future generations simply through soil. There are many ways to help the soil and help to provide for our future generations. One way is crop rotation. Crop rotation has been around for centuries. Crop rotation helps make the soil richer in things that other plants can’t do. Such as corn taking a lot of nitrogen out of the soil, it would be smart to plant nitrogen-fixing beans next in that soil. This helps to avoid having to spray the crop and allows farmers to save money and time, along with soil. It also helps to increase the crop yield. There are many ways soil impacts us. Whether through our world, or simply the food on our plate, soil has an important role in our society. Big or small, soil impacts our natural environment. We are truly providing for future generations to come.

Oklahoma Winner: Brylie Owen
Senior, Morris Public Schools
Instructors: Mr. Clark & Mrs. Burkett
FFA is the future farmers of America, and the foundation for this future is healthy soil. Soil allows for farmers to work the land and provide for America. Soil is a huge part of agriculture and plays an important role in the way of life. Crops are grown to feed the nation, soil connects communities, and is the starting point for all living things. I am a senior at Morris Public Schools, and I can say that soil has impacted my life tremendously. I raise Boer goats to show at livestock shows, and without the soil my animals would never survive. The grass, feed, straw, and bedding are all components needed to have a successful product for the show season. None of the things I mentioned above would be possible without soil. Not only has soil impacted me, it has impacted my community. We have a Morris Community Garden and it plays an important role in the lives of students. It provides a hands-on opportunity to understand how crops are grown, and how important soil is in the production of these crops. We have had the community garden for three years, and it has provided food for those in need. Not only does soil provide food for our community it provides jobs. Morris is a low-income community, and many people get their way of life from the soil. Our community is filled with farmers, so the soil is not producing food, it is producing the way of life.
The Milpa and First Acre Program originated in Central America where the Mayans used a mixture of corn, squash, and beans (“The Three Sisters”) to improve the soil and grow food. At Green Cover, we expanded on this technique and compiled a mix of over 40 different seeds. This is an excellent way to utilize a small portion of land to produce food without going through the hassle of hours of planning, tillage, and weeding. It is also a great way to rekindle the feeling of pride and satisfaction that comes from producing healthy food that is being directly consumed by family, friends, and neighbors.

The modern Milpa concept was launched in 2017 with a partnership between Green Cover and the Farm to Food Bank in Oklahoma. Green Cover donated Milpa garden seed to several regenerative farmers throughout Oklahoma who partnered with the Regional Food Bank of Oklahoma. The simplicity of the 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 provided the seed mixes which included fresh greens (turnips, collards, mustard), root vegetables (radishes, turnips), legumes (cowpeas, mung beans, black beans), and vine crops (squash, melons, cucumbers, pumpkins). The community came together to glean the produce, with members from various groups all pitching in to help feed their local area. 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 local relationships as well. These gardens also served as a diverse crop mix to help improve soil health, water quality, and habitats for pollinators and wildlife on these farms.

Ryan and Jennifer Speer of Sedgwick, Kansas, are Milpa garden veterans, having grown tons of produce over the last few years for their local community. “A typical garden is fairly high maintenance but the Milpa garden is straightforward,” notes Ryan. “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.”

First Acre Program

At Green Cover, 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 have partnered with The Nature Conservancy and Syngenta to accelerate our Milpa First Acre program. This program was started in 2018 to donate an acre of highly diverse Milpa garden seed to anyone willing to work with their local food banks or resource centers to help feed and build their local community. The program has grown slowly but now with the support of our partners, we will have enough seed to quadrupled our efforts and enroll more than 1,000 First Acre participants to provide them with free seed. We hope you’ll consider joining the First Acre program and adding an acre of Milpa to help build healthy people in your own community! If you are not a farmer but are interested in the program, consider spearheading an effort to connect local farmers and local civic or church groups to grow fresh, healthy produce for your community. For more information or to sign up for the Milpa First Acre Program, go to www.milpagarden.com.

Milpa Resiliency Gardens

Many of the 577+ federally recognized American Indian Tribes are agricultural Tribal communities with vast histories in farming. Collectively they own more than 53 million acres, have primary water rights, have a population of 3 million, and are growing at 4% per year. Many of the Pueblo communities in the southwest have been utilizing the same seed, the same waters, and the same soils for centuries. Agriculture is the very DNA that has made the people and the communities what they are. But fast forward to a more modern way of life and wage economies—farming becomes more challenging, as many travel an hour each way to work, put in a 12-hour work day, and then do their farming on top of that. Add a worldwide pandemic on top of that, and we have farming in 2020 and 2021.

When the pandemic first hit our community at the Pueblo of Jemez in Northwestern New Mexico, we were concerned about access to food. The closest grocery store is 47 miles away and the local convenience store stocks mostly unhealthy junk foods such as chips, soda, and candy. Our Cultural Leader, Joseph Toledo, gathered a few people and advocated calm and confidence amidst the headlines and news stories of empty grocery shelves. He suggested that since the beginning of time, we have had a symbiotic relationship with the natural world full of abundant resources with many edible and medicinal plants. We began foraging our landscapes for diverse varieties of these plants. We engaged our youth in virtual workshops to help support the identification of the correct plants. This was immensely helpful in restoring confidence in our cultural ways and dealing with the anxiety from being bombarded by the daily newsreels with death counts. It helped to get us outside and in small family groups to preserve our cultural ways. This was helpful but not the entire picture.

We knew that we would have to plant, and plant big in the spring. We had been practicing cover crop and no-till in our agricultural areas as practice for several years, and obtained great advice and seeds from Keith Berns at Green Cover. We historically blend cover crops, no-till and use of humates mined locally as our organic fertilizers into our practice for farming. We plant our traditional chili, corn, melons, and squash from our Heritage seeds. But with the short supply and increasing costs at the grocery stores, we wanted to plant other non-traditional vegetable crops as well. We began looking for organic and non-GMO seed suppliers, but soon found that seeds as well as toilet paper and meat were in short supply. After a frustrating search, I called Keith and he said he could help (as usual) and we started to order Milpa seeds from Green Cover. After we had the first order of Milpa in the ground, we reached out to Tribes across the US and started to support their efforts for Milpa Resiliency Gardens. We brought in big bags of Milpa seeds and broke them into smaller bags and sent seeds to more than 600 Native and Tribal farms from Alaska to Florida, California to Maine, and many places in between.

We received many requests for “how to” and more specifics on planting the Milpa blend into Resiliency Gardens. We spent a lot of time with individuals, families, and communities alike. It felt good to get the seeds into the soil all across Indian Country. With the help of Green Cover, the Native American Agriculture Fund, and various Tribal organizations, we were able to donate all the Milpa seed. All the produce and vegetables were grown and consumed on Indian lands for Native peoples.

We are working on our future Milpa seed orders now and are planning to work more efficiently with Tribal organizations across the country.

We highly recommend to anyone wanting to make a difference to consider joining the Green Cover Milpa project and invite others to help support growing their own food!
Be sure to add a good amount of diversity in your mix. We like to see 6-12 species in a mix, including at least one selection from each seed category.

**Step 1**
This is where you enter your details such as zip code, seeding method, next cash crop, acres, irrigated inches, seeding and 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, and plant hardiness zone for the selected zip code.

**Step 2**
Now the fun part—selecting the species for your mix! Based on the information given in Step 1, SmartMix® will rank all the species in categories of Excellent, Good, Marginal, and Risky. It will take into consideration your location, goals, planting and termination date, and next cash crop selection.

**Step 3**
Next, you will choose whether you will pick up your seed, or have it shipped to you. We are currently working on some new features for SmartMix®, including real-time shipping quotes, a checkout and payment process, and options to pick up or ship from our Iola, Kansas location as well as our Bladen, Nebraska facility. In the meantime, just give us a call if you have questions.

**Step 4**
This shows a summary of your mix. You can look over your selections, edit species, or adjust pounds per acre for each species. You can also add a comment or question in the comment box. You can decide to save your mix for later, or if you are ready to order, you can click the "Confirm & Complete" button. This will send the order to one of our staff for review. We do not finalize the actual order before talking to you first. Even if you are not ready to purchase a mix, you can still confirm and submit your mix and we will give you feedback on it. We will find the best shipping rate possible and answer any other questions you might have.

**Step 5**
This is the confirmation page where you will see your order submission number. You can also view any other mixes you’ve saved.

Our goal is to help people regenerate God’s creation for future generations. We believe SmartMix® helps fulfill that desire. If you have questions about SmartMix® or ideas to make it better, please email jakin@greencoverseed.com.

**What Do All Those Numbers Mean, Anyway?**
SmartMix® uses a number of meters reflecting the potential effects of your mix.

**Carbon-Nitrogen (C-N) Ratio** is an indication of how fast (low or soft C-N) or how slow (high or hard) the residue of your mix will break down and cycle. Using more legumes, having a shorter growing period, or grazing and allowing regrowth are all ways to lower the C-N ratio of your mix and cycle your nutrients faster.

The Full Rate gauge is an indication of the appropriateness of your seeding rate. We think 125% of a full seeding rate is about right for a diverse mix. If you are on a tight budget or very dry, you might consider lowering the seeding rate to 100% or less. If you are grazing livestock or want to max out the biomass production of your mix, increase your seeding rate to 150%-175%.

The Goals Progress sliders give an indication of how well your species selections and seeding rates will meet and achieve the goals that you set for your cover crop mix. Your primary goal should be as close to 100% as possible, and your second and third goals should be 75% or higher. You can add or remove species and change seeding rates to see how this will affect your Goals Progress sliders.

The Mix Effect Potential numbers give a relative rating of how your mix scores in each of these important areas. Feel free to change all of the variables in your mix to see how it affects the ratings. We often have people tell us that they spend hours playing and tweaking their mixes to try and get the best scores possible with the lowest cost mix. Give it a try!
Cover Crop Mixes

It has been observed that a mixture of plants often performs better than a monoculture of the best performing plant in that mix. Each plant species has unique liquid carbon roots that feed a diverse community of microbes, making 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” species. Plant diversity also provides different root types for better use of soil resources, a layered canopy to capture more sunlight, better nutrition for livestock grazing, and lower risk of any one insect or disease taking out the stand. Green Cover is the industry leader in designing and delivering customized diverse cover crop mixes. We encourage you to use the SmartMix® calculator (see pages 60-61) to experiment with building mixes, or call or email us (see back cover for contact information) to get help designing the best mix for you. To get you started, here are some basics of cover crop “mixology.”

Spring Mixes

Spring plantings are commonly utilized to jump-start soil biology after a long cold winter. These cover crop mixes are used to prime the soil biology ahead of a crop planted later in the spring. 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 mixes if the planting date is delayed until closer to the frost-free date.

Late Spring/Early Summer Mixes

Late spring and early summer plantings are often used 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. Because these mixtures consist of both cool season and warm season species, plant after the last frost risk has passed and when soil temperatures reach and maintain 55-60°F.

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 many cover crop options to choose from, these mixes will be driven by your specific goals. Midsummer mixes can also work well for early sillage fields and seedcorn fields. Warm season species will dominate these mixes with a few strategic cool season species added for diversity.

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 also present challenges for seeding the covers. Fall mixtures vary greatly depending on your goals, planting method, timing, and location. 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 possibly winter-hardy legumes 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.

Premade Cover Crop Mixes

While we specialize in making diverse blends tailor-made for each customer’s needs, we also offer predesigned mixes for specific situations, making it more cost effective for customers who have less than a couple of acres to plant.

Soil Building Mixes

- Cool Season Soil Builder Mix
- Warm Season Soil Builder Mix
- Mycorrhizal Mix — now with MycoMaxx
- High Diversity Mix

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 while keeping weeds suppressed. The Cool Season Mix can be planted in spring or fall while the Warm Season mix should be planted once soil temperatures stabilize above 65°F in late spring or summer.

Pollinator Mixes

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

We offer three different pollinator mixes to fit your needs throughout the year. There are about 1,700 insects that are beneficial. Why spend money on chemicals to target a few pests when fostering a habitat for beneficial insects can take care of the problem? The variety of bloom colors in these mixes will attract many different insects, benefiting both the plants and the soil.

Overwintering Mix

Not only is this a great mix for a garden, but for many cover crop situations. With overwintering potential in most parts of the country this mix will start growing in the fall and resume growth in the spring. This reduces winter and spring erosion thanks to living, diverse roots. Come April and May, this mix will produce enough biomass to suppress weeds and fix a bit of nitrogen for your soil.

Wildlife Food Plot Mixes

We have a full range of highly diverse food plot mixes for deer and upland game birds, including Summer Release and Fall Release, which have been co-developed with Dr. Grant Woods from GrowingDeer. For more details, visit www.greencoverfoodplots.com.

Food Plots

Visit our website to learn more about these mixes, including the specific ingredients of each mix, or to place an order. www.greencover.com
Legumes
Legumes are best known for their ability to fix atmospheric nitrogen that benefits the soil and following crops. In forage mixtures, legumes can be added to aid protein. They are also a valuable addition to mixes used to reduce erosion, build organic matter, and attract beneficial insects.

Wyoming Winter Peas
WyoWinter peas are a release from University of Wyoming that feature improved winter hardiness over Austrian winter peas. They can be used like Austrian winter peas, with the added benefit of being used in areas where Austrian winter peas do not reliably overwinter. WyoWinter peas are typically planted in fall, make limited fall growth, survive the winter and make explosive growth in spring. They are a good nitrogen fixer and good for livestock forage.

Cold Season Legumes

<table>
<thead>
<tr>
<th>Species</th>
<th>Seeds Per Pound</th>
<th>Cold Kill °F</th>
<th>Min. Soil Temp °F</th>
<th>Max. Height</th>
<th>Drought Tolerance</th>
<th>Biomass Production</th>
<th>Forage Quality</th>
<th>Salinity Tolerance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage soybeans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forage soybeans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balansa Clover (FIXation)</td>
<td>500,000</td>
<td>-5</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good winter hardiness</td>
</tr>
<tr>
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<td>42</td>
<td>36</td>
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<td></td>
<td></td>
<td></td>
<td>Drought tolerant</td>
</tr>
<tr>
<td>Balansa Clover</td>
<td>150,000</td>
<td>20</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mediterranean type</td>
</tr>
<tr>
<td>Persian Clover</td>
<td>150,000</td>
<td>20</td>
<td>42</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mediterranean type</td>
</tr>
<tr>
<td>Hubbl White Sweet Clover</td>
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<td>25</td>
<td>42</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Most shade tolerant</td>
</tr>
<tr>
<td>Yellow Sweet Clover</td>
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<td>-10</td>
<td>42</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Blanched - deep rooted, saline soils</td>
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<tr>
<td>Subterranean Clover</td>
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<td>20</td>
<td>38</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Listener Clover - perennial</td>
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<td>-15</td>
<td>40</td>
<td>12</td>
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<td></td>
<td></td>
<td></td>
<td>Long lived perennial</td>
</tr>
<tr>
<td>Rainbow Clover - perennial</td>
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<td>-10</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Short lived perennial</td>
</tr>
<tr>
<td>Alpine Clover - perennial</td>
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<td>-10</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerant of wet soils</td>
</tr>
<tr>
<td>Sainfoin - perennial</td>
<td>18,500</td>
<td>-15</td>
<td>42</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Drought tolerant</td>
</tr>
<tr>
<td>Alfalfa - perennial</td>
<td>150,000</td>
<td>-15</td>
<td>42</td>
<td>40</td>
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<td></td>
<td></td>
<td></td>
<td>Very productive legume</td>
</tr>
<tr>
<td>Persian Clover</td>
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<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mediterranean type</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>120,000</td>
<td>5</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fast growing clover</td>
</tr>
<tr>
<td>Berseem Clover (Balady)</td>
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<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mediterranean type</td>
</tr>
<tr>
<td>Berseem Clover (Balady)</td>
<td>150,000</td>
<td>20</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mediterranean type</td>
</tr>
<tr>
<td>Persian Clover</td>
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<td>20</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Long lived perennial</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>120,000</td>
<td>5</td>
<td>42</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Most shade tolerant</td>
</tr>
<tr>
<td>Arrowleaf Clover</td>
<td>270,000</td>
<td>15</td>
<td>42</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Drought tolerant</td>
</tr>
</tbody>
</table>


Sunn Hemp
Sunn hemp produces more biomass and more nitrogen in less time than any other legume. Unlike other legumes, sunn hemp has stalks that are fibrous, hard, woody, and persistent. While this is an advantage to soil-building, it can make planting the next cash crop difficult, as the fibers tend to wrap around any type of spinning equipment. Sunn hemp also exudes compounds from the roots that are toxic to many parasitic nematodes, including soybean cyst nematodes. Sunn hemp is highly palatable to sheep, goats, deer, but only the Tropic Sun variety is very palatable to cattle.

Laredo Forage Soybeans
Forage soybeans are varieties that grow more vegetatively than grain varieties and will typically produce more nitrogen as well. Laredo is the original forage soybean that has been used for over 100 years as a hay and forage bean. The small seed size (approximately 7,200 seeds/ib), black seed coat, and reseeding capability set them apart from other forage soybeans. Laredo forage soybeans are widely used as hay beans, green manure, and wildlife plantings as they will produce a large tonnage of high protein biomass.

Biology of Legumes

Legumes are best known for their ability to fix atmospheric nitrogen that benefits the soil and following crops. They have excellent palatability and regrowth.

Berseem Clover
Balady berseem clover is a single-cut variety that is quick growing and is a nice fit for a short growing season. Frosty Berseem clover is a multi-cut variety that is capable of producing multiple cuttings or grazings in a single season. For more information on Frosty Berseem, visit www.frostyclover.com.

Persian Clover
Persian clover is extremely tolerant of wet soils, and has excellent forage quality. Pairing with a mixture of oats or ryegrass will reduce the risk of bloat.

Hairy Vetch—AU Merit
Hairy vetch is the most winter hardy annual legume, and is probably the best nitrogen fixer as well. Hairy vetch produces a dense mulch that is an ideal no-till seed bed for forage mixtures, legumes can be used to add protein. They are also a valuable addition to mixes used to reduce erosion, build organic matter, and attract beneficial insects.
Grasses
Grasses generally produce the highest yields and greatest biomass of all the plant species. Grasses comprise the bulk of many mixes, including most grazing mixes, and are generally very palatable for livestock. These plants tend to be higher in carbon-to-nitrogen ratio and can provide excellent residue if allowed to go to maturity.

Elbon Cereal Rye
Elbon has a wonderful combination of winter hardiness and fast growth. It has a shorter dormancy period than northern cereal rye, and will give more fall growth as well as earlier spring growth. Elbon is excellent as a forage in early spring and will provide weed suppression and erosion control well into the early months of summer as a mulch. It can be planted late in the season into soils as cold as 34°F.

Montech Forage FX 1001
Montech Forage FX 1001 winter triticale is a true beardless triticale with one of the best combinations of winter hardiness and forage production on the market. Taller and slightly earlier to mature than most northern triticales, Forage FX 1001 has shown exceptional production on dryland acres even with little spring rainfall. Bred in the harsh northern climate of Montana, this is a great choice for the central and northern Great Plains region.

Elbon is a cross between wheat and cereal rye and has some characteristics of each parent. Compared to cereal rye, triticale holds its feed value better into late spring. This makes it well suited for hay, baleage, or silage. Triticale is also excellent for grazing and, with proper management, can be grazed well into June. Triticale tends to be a bit more susceptible to winter injury than rye, but is similar to wheat for winter hardiness.

TriCal SY 813
813 is awnletted (very short beards), has excellent fall growth and vigor, and is tolerant of both rust and wheat streak mosaic virus. It is a medium-maturity triticale, has good straw strength and is very well adapted to the southern and central Great Plains region. A great choice for silage or baleage.

Sorghums
Abundant and rapid growth makes plants in the sorghum family an excellent warm season cover crop option for grazing, haying, suppressing weeds, and building the soil. There are many purposes for which sorghum plants are suited, and different types and traits have been developed to meet these needs.

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

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.

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

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.

Fall grazing: 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-sudan is preferable.
Grasses

**Biomass production and cover:** Conventional sorghums and sunhemp-sudans are the least expensive, but often times 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 a 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 staples for human consumption. There are a variety of different millets that serve an array of purposes. It is important to understand the different types of millets as well as when and where they should be used.

Pearl Millet *(Genus Pennisetum)* 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. It is usually higher in protein than sorghum, but loses palatability more rapidly upon maturity. Unlike sorghums, pearl millet is safe for horses.

Japanese millet *(Genus Echinochloa)* matures rapidly and typically yields less forage than other millets. It is more palatable than forage millet after maturity and has better regrowth. Japanese millet is exceptionally tolerant of wet soil and will even grow in standing water, making it well-suited for duck food plots.

Proso millet *(Genus Panicum)* 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.

**Barley**

**Lavina Spring Barley**

Lavina spring barley is a vigorous variety of two-rowed, beardless forage barley. Lavina, like other barley varieties, is one of the most tolerant crops of salty or high pH soils. Barley is a cool season crop, able to grow at temperatures as low as 40°F. Lavina can be planted in the late summer and have abundant fall growth prior to winterkilling when temperatures drop into the teens, or it can be spring planted once soil temperatures rise above 40°F. In a spring planting, Lavina will head out and can be harvested as either pasture, hay, or grain as needed.

**Cosaque Black Oats**

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

---

**Warm Season Grasses**

<table>
<thead>
<tr>
<th>Name</th>
<th>Seeds/Per Pkt</th>
<th>Cold Kill °F</th>
<th>Min. Sal Temp °C</th>
<th>Mature Height</th>
<th>Drought Tolerance</th>
<th>Biomass Production</th>
<th>Fodder Quality</th>
<th>Salinity Tolerance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMR Grazing Corn</td>
<td>2,500</td>
<td>32</td>
<td>50</td>
<td>84°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very high value for forage</td>
</tr>
<tr>
<td>Sorghum Sudan</td>
<td>18,000</td>
<td>32</td>
<td>62</td>
<td>96°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High tonnage</td>
</tr>
<tr>
<td>BMR Sorghum Sudan</td>
<td>18,000</td>
<td>32</td>
<td>62</td>
<td>96°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low lignin</td>
</tr>
<tr>
<td>BMR Sorghum Sudan PPS</td>
<td>18,000</td>
<td>32</td>
<td>62</td>
<td>144°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Photoperiod sensitive</td>
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<tr>
<td>Sudangrass</td>
<td>22,000</td>
<td>32</td>
<td>62</td>
<td>96°</td>
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<td></td>
<td></td>
<td></td>
<td>Fine stemmed</td>
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<tr>
<td>Forage Sorghum</td>
<td>18,000</td>
<td>32</td>
<td>62</td>
<td>120°</td>
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<td>Great for silage</td>
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<tr>
<td>Egyptian Wheat</td>
<td>18,000</td>
<td>32</td>
<td>60</td>
<td>132°</td>
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<td></td>
<td></td>
<td>Super tall sorghum</td>
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<tr>
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<td>32</td>
<td>62</td>
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<td>Good for upland birds</td>
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<td>Pearl Millet</td>
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<td>65</td>
<td>72°</td>
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<td></td>
<td></td>
<td></td>
<td>Highest production millet</td>
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<td>Browntop Millet</td>
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<td>32</td>
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<td>48°</td>
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<td></td>
<td></td>
<td></td>
<td>Great heat tolerance</td>
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<td>Japanese Millet</td>
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<td>55</td>
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<td></td>
<td></td>
<td></td>
<td>Grows in wells soils</td>
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<tr>
<td>Proso Millet</td>
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<td>32</td>
<td>60</td>
<td>30°</td>
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<td>Grain millet for birds</td>
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<tr>
<td>German Millet</td>
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<td>55</td>
<td>48°</td>
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<td></td>
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<td>Excellent hay millet</td>
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<tr>
<td>White Wonder Hay Millet</td>
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<td>55</td>
<td>52°</td>
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<td></td>
<td></td>
<td></td>
<td>Excellent hay millet</td>
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<tr>
<td>Teff Grass</td>
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<td>60</td>
<td>30°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very fine stemmed</td>
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**Cool Season Grasses**

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<thead>
<tr>
<th>Name</th>
<th>Seeds/Per Pkt</th>
<th>Cold Kill °F</th>
<th>Min. Sal Temp °C</th>
<th>Mature Height</th>
<th>Drought Tolerance</th>
<th>Biomass Production</th>
<th>Fodder Quality</th>
<th>Salinity Tolerance</th>
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<td>38</td>
<td>48°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very versatile</td>
</tr>
<tr>
<td>Black Oats (Cosaque)</td>
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<td>10</td>
<td>38</td>
<td>52°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Great forage, long season</td>
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<tr>
<td>Winter Oats (Bibi)</td>
<td>19,000</td>
<td>10</td>
<td>38</td>
<td>48°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oversewers in the South</td>
</tr>
<tr>
<td>Spring Trifoliate (Surgo)</td>
<td>16,000</td>
<td>5</td>
<td>38</td>
<td>54°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Awelested, high spring production</td>
</tr>
<tr>
<td>Spring Forage Barley (Lavina)</td>
<td>13,000</td>
<td>20</td>
<td>38</td>
<td>36°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Barleasted and salt tolerant</td>
</tr>
<tr>
<td>Winter Barley (PY19)</td>
<td>15,000</td>
<td>0</td>
<td>38</td>
<td>30°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Barleasted, winter hardy</td>
</tr>
<tr>
<td>Cornell Rye (Elbon)</td>
<td>22,000</td>
<td>30</td>
<td>34</td>
<td>72°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Best weed suppression</td>
</tr>
<tr>
<td>Cornell Rye (Yankee)</td>
<td>20,000</td>
<td>0</td>
<td>34</td>
<td>72°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Northern type with bigger, hollow stem</td>
</tr>
<tr>
<td>Winter Trifoliate (SY813)</td>
<td>16,000</td>
<td>10</td>
<td>38</td>
<td>60°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Great spring forage</td>
</tr>
<tr>
<td>Winter Forage Wheat (Goral)</td>
<td>13,000</td>
<td>10</td>
<td>38</td>
<td>52°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very long season for later grazing</td>
</tr>
<tr>
<td>Soft Red Winter Wheat (Gara)</td>
<td>13,000</td>
<td>10</td>
<td>38</td>
<td>40°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Barreasted, good grazing</td>
</tr>
<tr>
<td>Italian Ryegrass</td>
<td>190,000</td>
<td>0</td>
<td>40</td>
<td>36°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Blainna- best for spring planting</td>
</tr>
<tr>
<td>Annual Ryegrass</td>
<td>190,000</td>
<td>0</td>
<td>40</td>
<td>36°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very deep rooted</td>
</tr>
</tbody>
</table>

---

**Cool Season Grasses Chart Key:**

- **Poor**
- **Fair**
- **Good**
- **Excellent**

---

**Teff Grass**

Very fine stemmed

---

**Forage Sorghum**

Great for silage

---

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

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**Browntop millet (Genus Urochloa)** is fast-maturing, but lower-yielding than pearl millet. It is commonly used in the southern plains, as it is more tolerant to higher humidity levels, but it can move north as well. Browntop holds its palatability after maturity better than other millets, making it a good 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.

---

**Grasses**

**Foxtail Millet | Right: Pearl Millet. 5 weeks of growth.**
Brassicas

Brassicas are an excellent addition to many cover crop mixes because of their ability to suppress weeds and break up soil compaction. Brassicas are also used for nutrient scavenging and producing a high amount of biomass in the fall. They can be a great component of a grazing mixture, but in most cases we would not recommend more than 2-3 lbs per acre in a mix.

Radish

Radishes have probably done more to promote cover cropping than any other species except cereal rye. The tremendous deep taproots of a forage radish can break up compaction and increase the rooting depth of the following crop. Radishes are great at scavenging nutrients such as N, P, and K, making it a great option in the fall directly after corn harvest to help prevent leaching.

Turnips

Like radishes, turnips are well known and widely used as a cover crop. Their taproot does not penetrate as deep as that of a radish, but turnips have a very high sugar content, making them extremely palatable for livestock such as N, P, and K, making it a great option in the fall directly after corn harvest to help prevent leaching.

Collards

Collards are one of the most heat-tolerant brassicas as well as one of the best for grazing. They are very palatable and tolerate midsummer planting better than most brassicas. The regrowth potential of collards after grazing is exceptional, and they will grow later into the fall than most brassicas. For multiple grazings, collards are tough to beat.

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Camelina

Camelina is the most winter-hardy of the brassicas, and quite likely the most drought tolerant. It has smaller seed than most other brassicas and thus requires a very low seeding rate. In other respects, camelina performs similar to rape-seed. We are still learning about this promising crop and what benefits it can offer to farmers.

Mustards

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 four mustards that are a relatively long season producer. Collards are great at scavenging nutrients such as N, P, and K, making it a great option in the fall directly after corn harvest to help prevent leaching.

P Returns Chart Key: Poor Fair Good Excellent

<table>
<thead>
<tr>
<th>Brassicas</th>
<th>Min. Soil Temp °F</th>
<th>Mature Height</th>
<th>Drought Tolerance</th>
<th>Biomass Production</th>
<th>Forage Quality</th>
<th>Safety Tolerance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daikon Radish (Nitro)</td>
<td>30</td>
<td>15</td>
<td>45</td>
<td>24</td>
<td></td>
<td></td>
<td>Deep taproot</td>
</tr>
<tr>
<td>Smart Radish</td>
<td>30</td>
<td>15</td>
<td>45</td>
<td>24</td>
<td></td>
<td></td>
<td>Pull down taproot</td>
</tr>
<tr>
<td>Forage Radish (Giza)</td>
<td>30</td>
<td>15</td>
<td>45</td>
<td>28</td>
<td></td>
<td></td>
<td>Slow bolting</td>
</tr>
<tr>
<td>Oilseed Radish (Centra)</td>
<td>30</td>
<td>15</td>
<td>45</td>
<td>24</td>
<td></td>
<td></td>
<td>Nematode suppression</td>
</tr>
<tr>
<td>Forage Collards (Impact)</td>
<td>175</td>
<td>5</td>
<td>40</td>
<td>30</td>
<td></td>
<td></td>
<td>Great grazing forage</td>
</tr>
<tr>
<td>Purple Top Turnips</td>
<td>175</td>
<td>10</td>
<td>45</td>
<td>24</td>
<td></td>
<td></td>
<td>Great value for grazing</td>
</tr>
<tr>
<td>Hybrid Turnip (Viva, Hunter)</td>
<td>175</td>
<td>15</td>
<td>40</td>
<td>28</td>
<td></td>
<td></td>
<td>Excellent regrowth</td>
</tr>
<tr>
<td>Forage Rapeseed (Triumph)</td>
<td>175</td>
<td>5</td>
<td>41</td>
<td>36</td>
<td></td>
<td></td>
<td>Lowest-cost brassica</td>
</tr>
<tr>
<td>Hybrid Rape/Kale (Bayou)</td>
<td>175</td>
<td>0</td>
<td>43</td>
<td>48</td>
<td></td>
<td></td>
<td>Great winter forage</td>
</tr>
<tr>
<td>African Cabbage</td>
<td>180</td>
<td>15</td>
<td>42</td>
<td>48</td>
<td></td>
<td></td>
<td>Stands well in winter</td>
</tr>
<tr>
<td>Camelina</td>
<td>180</td>
<td>15</td>
<td>40</td>
<td>24</td>
<td></td>
<td></td>
<td>Most cold-hardy brassica plant</td>
</tr>
<tr>
<td>Florida Broadleaf Mustard</td>
<td>150</td>
<td>25</td>
<td>40</td>
<td>36</td>
<td></td>
<td></td>
<td>Huge leaves – best mustard for grazing</td>
</tr>
<tr>
<td>White Gold Mustard</td>
<td>150</td>
<td>25</td>
<td>40</td>
<td>36</td>
<td></td>
<td></td>
<td>Best weed suppression mustard</td>
</tr>
<tr>
<td>Kodiak Brown Mustard</td>
<td>150</td>
<td>25</td>
<td>40</td>
<td>42</td>
<td></td>
<td></td>
<td>Nematode suppression</td>
</tr>
<tr>
<td>Indi Gold Oriental Mustard</td>
<td>150</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td>Nematode suppression</td>
</tr>
</tbody>
</table>

African Cabbage

African cabbage differs from other brassicas in that it does not decompose right after winter killing. It has a woody central stem that remains erect through the winter, providing soil protection and trapping snow, therefore retaining more moisture. It has poor grazing palatability compared to other brassicas, but it is tasty to humans, with a flavor similar to head cabbages.

Vivant Hybrid Turnip

Vivant Hybrid Turnip is a new, fast-growing, leafy brassica with little bulb development. It is best suited for multiple grazing. Vivant bolts very late and has vigorous regrowth after grazing, while maintaining high feed quality and digestibility.

With proper management, Vivant has the potential to yield up to 10,000 lbs of dry matter per acre over multiple grazing events. Vivant can be planted with cereal grains or annual ryegrass in the spring or late summer to provide excellent tonnage and high quality forage.
Broadleaves

Broadleaves are a great way to add diversity to a cover crop mix. Most broadleaves have extensive root systems that are fantastic for soil building. Broadleaves can also be used for compaction breaking, erosion control, and attracting beneficial insects.

Flax

Flax is a cool season annual that offers great value as a cover crop due to its excellent ability to host mycorrhizal fungi and to provide persistent residue, unlike most other cool season broadleaves.

Flax stems stay upright in winter, acting as a great snow catch. Flax has little to no grazing value, but can still be a good option in grazing mixes because the residue left after grazing will protect the soil. The blue flowers of flax are a sight to behold, and it makes a nice addition to a variety of pollinator mixes.

Phacelia

Phacelia scavenges nitrogen in the soil and provides carbon to build soil organic matter. It can be used for feed or hay in soil with low to medium nitrogen availability. Although the forage yield is low, livestock find it palatable, even at advanced stages of maturity. Phacelia performs best when planted in early spring or late summer, as additional forage for livestock and are preferentially grazed when younger. Sunflowers also are good for mycorrhizal fungi growth.

Sunflower

Sunflowers have a fantastic root system that enables them to capture available nutrients in the soil. Sunflowers are a great option in any summer cover crop mix because of their root system and their attractiveness to beneficial insects. Because sunflowers can add significant biomass production in a short growing season, they can also serve as additional forage for livestock and are preferentially grazed when younger. Sunflowers also are good for mycorrhizal fungi growth.

Safflower

Safflower is a drought tolerant, warm season, annual 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, and scavenging nutrients from deep down in the soil profile. 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 safflower can be handled with bare hands even at maturity and is palatable for livestock grazing. Though safflower resembles a thistle, it doesn’t pose a weed risk due to its long maturity date.

Gourds & Pumpkins

Gourds and pumpkins can be a very valuable addition to a cover crop mix. Due to their vining nature, they can creep along and find gaps in the canopy of taller plants, using that otherwise unutilized sunlight to produce fruits edible to livestock or earthworms, rather than allowing that sunlight to eventually lead to a crop of weeds. Vining plants like these species can provide cover and protection to spots in a field where growth is often very difficult, such as salty spots or pockets of blow sand.

Phacelia (SuperBee) 225,000 25 42 30” Fantastic pollinator attractor

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Buckwheat

If you need a workhorse to attract beneficial insects and pollinators, buckwheat is an exceptional choice. This species can be used in a low residue, winter kill, pollinator or summer soil builder mix. Buckwheat’s claim to fame is through its known ability to extract phosphorus and other nutrients from the soil and render them more available for the next crop. Buckwheat’s vigorous growth habits make it ideal for a quick establishing crop with superior weed suppression. Flowering can occur in the first three weeks of growth and continue on for 10 weeks. Its flowers attract a large array of beneficial and pollinator insects. If soil moisture usage is a concern, buckwheat is a good option. Buckwheat uses about half as much water as a soybean crop.
Perennials

The most reliable source of pasture for livestock is a blend of perennial forages. Since perennials are already established, they do not rely on an annual planting operation that can be delayed by weather. Perennials have deep and well-established root systems that convey greater drought tolerance compared to annual pastures. Perennials come in different forms, each with advantages and disadvantages, and all play a role in an intelligently designed forage plan.

Warm Season Grasses

Warm season grasses have a different photosynthesis method than most plants, called C4 photosynthesis. This enables them to grow very rapidly during hot weather (their optimum temperature is about 90°F), and they require only half as much water as cool season grasses to produce a unit of dry matter. But they have a short growing season, only growing when temperatures are above 60°F. They also lose quality rapidly upon maturity, especially in the more productive tropical and humid area grasses. Examples of warm-season perennial grasses include:

- **Native tallgrasses** like big bluestem, Indiangrass, switchgrass, and little bluestem are still found in some areas as native stands. These grasses are also being increasingly reseeded due to their excellent summer quality and drought tolerance compared to cool season grasses. They have poor forage quality after maturity and need protein supplementation if grazed during winter. Due to their lower protein content compared to cool season grasses, their nitrogen requirements per ton of production are also lower.

- **Eastern gamagrass** is a native grass that requires different management than most other grasses. It is extremely productive and high in quality, but it is expensive and has been historically difficult to establish. New establishment techniques have made getting a stand of gamagrass much more assured than in the past, though it is still difficult. Gamagrass provides excellent wildlife habitat and coexists very well with many legumes and forbs. Gamagrass requires top-level grazing management, as it can be killed by overgrazing.

- **Bermudagrass** is extremely high-yielding but produces lower animal gains than the native grasses. Bermudagrass becomes a far less attractive option in northern latitudes of the US, with stands in northern Kansas roughly half as productive as similar stands in southern Kansas. Bermudagrass tends to form monocultures and crowds out many other plants, although we are finding that alfalfa can compete with bermudagrass if planted in the fall, and many winter annuals (like winter peas, crimson clover, rye, and annual ryegrass) can be seeded each fall and grow well in bermudagrass sod. Monoculture bermudagrass requires high rates of nitrogen to obtain high yields. Bermudagrass spreads rapidly through creeping stolons (runners). This trait can make it an invasive pest, but also makes it able to recover rapidly from trampling and overgrazing. It can handle more animal load traffic than perhaps any other perennial grass and still survive. It tolerates severe grazing very well.

Cool Season Grasses

Cool season grasses grow well in cool and moist conditions, including temperatures too low for warm season grasses (between 40-60°F). They do not grow well when temperatures exceed 90°F, and their optimum temperature is about 77°F. They require more water and more nitrogen to produce a unit of dry matter than warm season grasses, but are often more productive than warm season grasses in humid areas due to their longer growing season. They grow poorly in July and August in many areas due to excess heat. Most combine very well with legumes such as red and white clover. Examples of cool season grasses include:

- **Tall fescue** is the most common cool season grass in the US. It grows well in poor soils and is able to survive close grazing. Tall fescue has a reputation of being poor-quality forage, and this is true for the widespread Kentucky 31 variety which contains an endophyte fungus growing inside the root system. This endophyte gives the plant protection from drought and disease, but decreases the palatability and the usefulness of the plant. The endophyte produces toxins that reduce animal performance. Varieties were developed that lacked this endophyte but it was discovered that the endophyte is what gave K31 fescue its toughness, and the fungus-free varieties often died with-in a few years. Now there are "friendly" or "novel" endo-phyte varieties that contain an endophyte that does not produce toxins. In areas where fescue is popular, these are the only tall fescue varieties we recommend for livestock forage. These varieties include E34+ and Estancia. E34+ is a soft leaf fescue and probably the best-quality tall fescue for spring and fall grazing. Estancia is an erect leaf fescue that works better for winter stockpiling, as it is more accessible in snow than a soft leaf, and it appears to be a bit more drought tolerant than E34+. When it comes to winter stockpiling, tall fescue is better than just about any other grass. No other grass maintains its quality as well in winter as fescue, often remaining over 14% protein, with digestibility over 70%, which is better than most of the hay fed across the country. To stockpile fescue, simply remove livestock from the pasture at or before early August and allow the plants to grow until growth ceases in the fall, which is around mid-November here in Nebraska. Good nitrogen availability is important for fall growth. Fertilizer applied in August or a good stand of legumes can provide this.

- **Orchardgrass** is a bunch grass that regrows well through summer and fall compared to other cool season grasses. Older varieties lack drought tolerance and are very susceptible to rust. Newer varieties work much better and enable orchardgrass to move out onto the Plains where it has not persisted well historically.

- **Smooth brome** is palatable and productive, with good drought tolerance. It is a sod-former and good for soil conservation. It does not tolerate severe grazing well, and regrowth in summer and fall is very poor, with almost all the yield occurring in spring. Smooth brome is aggressive and tends to form monocultures. It is recommended only in small amounts in pastures.

Meadow brome is a bunch grass resembling smooth brome but behaving like orchardgrass with more drought tolerance. Like orchardgrass it has good regrowth and is one of the better grasses for stockpiling in winter, though it is still distinctly inferior to fescue for that purpose.

- **Reed canarygrass** has very high tolerance to wet soils and is probably the highest-yielding cool season grass where there is sufficient moisture. Wild stands of reed canarygrass are very unpalatable due to a high content of alkaloids, but low alkaloid varieties offer good forage quality. Alkaloids are inactivated in the rumen by tannins (found in birdsfoot trefoil and chicory, among other plants) and to a lesser extent by saponins (found in alfalfa and clovers) so mixing these plants in with canarygrass greatly improves animal performance. It is a sod-former and creates a dense root mass that holds animals and vehicles up even in wet weather.

Perennial ryegrass is hands down the highest-quality perennial grass. It can produce animal performance equivalent to a grain diet, with a reputation for producing excellent tasting meat. Unfortunately, perennial ryegrass has historically been unable to survive in areas with severe winters or hot, dry summers—which describes much of the United States and particularly the Plains. Remington +NEA2 is a new ryegrass variety with a friendly endo-phyte that imparts a degree of heat and drought tolerance to perennial ryegrass, making this variety a good option for people who want to grass-finish livestock.

Wheatgrasses offer more drought tolerance than the above cool-season grasses but generally of lower forage quality. Western wheatgrass is a low-yielding but drought tolerant native grass that forms an open sod. Pubescent wheatgrass is a sod-former that rivals brome for productivity.
Legumes

Alfalfa is the most productive of the legumes. It is deep-rooted, drought tolerant, and high in quality until it reaches seed maturity. However, it requires a high level of management if it is to be grazed, needing rotational grazing and measures for bloat prevention. For hay, alfalfa is hard to beat. Plants usually live 3-10 years. Alfalfa is autotoxic, and established plants exude a toxin that prevents new seedlings of alfalfa from establishing, so stands do not reseed.

Red clover is highly productive—almost as productive as alfalfa—but plants only live 2-3 years before succumbing to diseases like anthracnose. It is easy to establish by broadcast seeding in winter. Modern varieties tend to live longer than common seed. Red clover rarely causes bloat, especially in mixtures with grass. Red clover is not autotoxic, so thin stands can be thickened by overseeding.

White clover is a common legume with exceptional forage quality. It spreads by stolons (runners) so it can thicken over time. Unlike most legumes, it is tolerant of severe grazing and often is very common in overgrazed pastures. White clover is shallow-rooted, and is very unproductive in drought. It is easily established by broadcasting in winter. White clover can cause bloat, but rarely does so if mixed with grass. Ladino clover is a large-leaved variety that is far more productive than the common Dutch white clover, which is very low-growing. Intermediate types like Louisiana S-1 and new varieties like Stamina are more heat and drought tolerant. AberLasting is a hybrid of white clover and the deep-rooted kura clover. AberLasting combines the best of both species, giving a plant with the drought tolerance and productivity of kura with the ease of establishment of white clover.

Birdsfoot trefoil is non-bloating due to its content of tannins, which have multiple benefits to grazing animals. It is about half as productive as alfalfa in good soils but is more tolerant of acid soils and does well in wet areas. It has poor seedling vigor and is slow to establish.

Alsike clover is very tolerant of wet soils, and provides high-quality forage. It does have some toxicity to horses so should be omitted from horse pasture mixes.

Sainfoin is a high quality, non-bloating, drought tolerant legume, adapted to shallow, gravelly limestone soils. It does not tolerate grazing well and disappears rapidly unless grazing is rotational and light.

Forbs

Chicory is a very productive, palatable, and deep taprooted forb that resembles a large dandelion, but with multiple blue flowers. The foliage is high in protein, very digestible, and high in phosphorus, copper, and zinc, which are deficient in most forage plants. It has polyphenols similar to tannin that help eliminate intestinal parasites and reduce bloat.

Plantain is a low-growing forb that, like chicory, is high in minerals. It also contains a natural antibiotic compound that helps reduce infections and also modifies rumen fermentation to improve animal performance, similar to an ionophore like Rumensin. It grows very well on compacted soils and helps loosen them.

Small burnet is a deep-rooted drought tolerant forb. It is high in tannin, which helps reduce intestinal parasites as well as bloat. It maintains its forage quality in winter very well, similar to tall fescue.

“The Health of soil, plant, animal and man is one and indivisible.”

Albert Howard
A clear purpose and 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. We want to share them with you, and encourage you to consider what your personal purpose and core values are.

**Our Purpose**
To help people regenerate God’s creation for future generations.

**Value Statement**
Green Cover 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.

**Our Core Values That Guide and Direct Us**
- **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 twelve years, but the people that make up the Green Cover team have been and will always be the most important part of our success. Almost everyone here works in more than one area, but here is where we spend the majority of our time!

**Support Team:**
- Hannah Nelson
- Noah Young
- Wyatt Smith
- David Nelsen
- Jon Holl
- Rebecca Licking
- Doris Zuellner

**Farm Team:**
- Jonathan Ellis
- Cory Simpson
- Brian Berns

**Maintenance Team:**
- Luke Sheltrown
- Travis Berns
- Alex Ding
- Tim Hinrichs
- Jacob Hinrichs
- Victor Alvarado

**Outside Operations Team:**
- Keaton Foster
- Jared Hynes
- Joe Melnick
- Stan Ellis

**Inventory Team:**
- Teri Anderson
- Doug Hylle
- Riley Meredith
- Josh Berns

**Seed Mixing Team:**
- Tyler Licking
- Glen Brumbaugh
- Suzanna Sheltrown
- Joseph Kirchner
- SynDee Wulf
- Walker Aufdenkamp
- Arvela Gabriel
- Jon Jones
- Chelsi Gonzalez
- Shawn Wiley

**Sales Team:**
- Davis Behle
- Jakin Berns
- Keith Berns
- Dale Strickler
- Zach Lusk
- Shelby Walker
- Colten Catterton

**Seed Production and Grower Relations:**
- Scott Ravenkamp

2021 was a challenging year for many industries as transportation issues plagued the country; however, we have maintained good relationships with our freight companies and will continue to provide nationwide shipping at a fair price. Nevertheless, we encourage our customers to plan ahead and order seed early to ensure a timely delivery.

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

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.
Nebraska Facility

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 is able to provide customers with quality seed at an affordable price. We contract seed production with growers in Nebraska, Kansas, Colorado, Missouri, Oklahoma, Texas, Florida, South Dakota, Montana, Idaho, Oregon, Tennessee, North Dakota, and Canada.

At our Nebraska location, we have built more than 40,000 square feet of warehouse and production facilities as well as bulk storage for more than 500,000 bushels over the past 10 years, and more storage and automation is being planned for future expansion. This facility allows us to fulfill most orders within 24 hours. Even during peak seasons we are still able to fulfill orders within 1-2 days.

World-Class Cleaning System
We have invested heavily in our cleaning facility to ensure you are receiving only the highest quality cover crop seed. Bin-run seed has the advantage of being cheap, but you never know what you are actually going to get. More often than not, you end up paying more for the waste than viable seed. Germination, purity, and overall quality are tremendously improved through our seed cleaning process. Our Q-Sage seed cleaner utilizes state-of-the-art technology and can condition 500 bushels of seed per hour through its 5½ screen shoes. Coupled with a deheader and two high-capacity gravity tables, 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, we take pride in our commitment to design custom cover crop mixtures for each customer to meet their individual goals and needs. This is one of the most labor-intensive methods used to manufacture a product, but we believe it is the best solution for each customer to receive a mix that meets your goals. To offset this and ensure a timely order fulfillment, we have invested 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. Our mix specialists are able to pull from our diverse inventory of over 150 cover crop species and weigh each product out with accuracy. 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!
A Note From Our CEO

Congratulations on reading this tome of soil health from cover to cover! If, however, your reading habits are more like mine and you started at the back of this guide, I encourage you to make sure you do not miss out on the plethora of information to be derived from the vast variety of authors’ passions, education, and experiences.

If you are ready to take the next step in your soil health journey, consider visiting the Green Cover website. We have many videos and articles about soil health as well as links to some of our favorite regenerative agriculture resources on the internet. When you are ready to put some of your newfound knowledge to work in your own soil, our SmartMix® calculator can guide you through developing a custom mix formulated to meet your specific goals and needs. Many of our customers report drafting multiple mixes and price points for numerous varying scenarios. The SmartMix® calculator allows you to see all your options! If the SmartMix® system gives you too many options or your operation is unique and real person guidance would be helpful, give us a call or send us an email and one of our experts will be happy to assist you.

We are proud and excited to continue the same great Green Cover service to our customers in Kansas and the southeastern states. Zach Louk, one of our sales representatives, has lived in the Iola area his entire life and is a farmer and rancher as well. We have also moved Dale Strickler to the Iola facility to help assist as many customers as possible. The practical tactical brilliance and knowledge of our sales representatives in Iola and Bladen help our customers increase their knowledge and understanding of cover crops.

Kansas Facility

The Green Cover facility in Iola, Kansas, is conveniently located 70 miles from Oklahoma, 45 miles from Missouri, and 140 miles from Arkansas. The facility is 54,000 square feet, and houses a new mixing system to allow us to handle mixes of any size from this location. We have approximately 42,000 square feet of flat storage to be able to keep up with demand and ensure a full inventory. We have spent the last 2 years establishing infrastructure, personnel, and logistics to be better able to serve more of our customers with affordable freight costs and fast shipping time.

In addition to the warehouse and mixing areas, we have completed an indoor grow room where we can grow cover crops and do year-round experiments and demonstrations. This 1,750 square foot room is located in the climate controlled portion of our warehouse, giving us the ability to grow both warm and cool season plants all year long. We love to utilize this grow room as an educational classroom and give tours to our customers and other interested parties. The grow room is also used to do elaborate demonstrations for field days and our annual Southeast Kansas Soil Health Conference.

If you are familiar with the use of monoculture cover crops, but are now ready to try a highly diverse mix of cover crop species, then contact one of our cover crop experts and we will show you how diversity can move you toward your goals. Our team loves opportunities to fulfill our purpose by helping you regenerate God’s creation for the future generations!

By David Nelsen

David has been with Green Cover for more than five years now and serves as the CEO. His military and manufacturing background plus his ability to see the big picture allow him to integrate the many functions of Green Cover!

He and his wife Britny and their seven children live on a small farm south of Red Cloud, Nebraska.
Our Locations
Bladen, NE 68928 • (402) 469-6784
Iola, KS 66749 • (620) 363-0653

Our Sales Team

Keith Berns
Green Cover • Bladen, NE
keith@greencoverseed.com
(402) 204-8946

Davis Behle
Green Cover • Bladen, NE
davis@greencoverseed.com
(308) 293-6584

Jakin Berns
Green Cover • Bladen, NE
jakin@greencoverseed.com
(402) 469-3234

Colten Catterton
Green Cover • Maryville, MO
colten@greencoverseed.com
(402) 984-1631

Dale Strickler
Green Cover • Iola, KS
dale@greencoverseed.com
(785) 614-2031

Zach Louk
Green Cover • Iola, KS
zach@greencoverseed.com
(620) 363-0653

Our Sales Partners

North 40 Ag, Kate Vogel • Ballantine, MT
kvogel@north40ag.com • (406) 600-5205

The Pence Group, Doug Griffin • Lafayette, IN
doug@pencegroup.net • (765) 426-1514

Brown Ranch, Gabe Brown • Bismarck, ND
brownranch@bektel.com • (701) 527-5570

Jonathan Cobb • Rogers, TX
jcobb@greencoverseed.com • (254) 231-5877

Brad McIntyre • Caldwell, ID
farmerbrad71@gmail.com • (208) 573-2182

Greg Scott • Tryon, OK
gregscott@cotc.net • (405) 413-2681

John Heermann • Haxtun, CO
johnheermann@gmail.com • (970) 520-9818

Philip Frank • Fruita, CO
philipfrnk@gmail.com • (970) 623-1316

Dale Family Farms, Kurt Dale • Protection, KS
kurt11dale@gmail.com • (620) 622-7008

Morales Feed & Supply, Daniel Morales • Devine, TX
daniel@moralesfeedandsupply.com • (210) 416-6415